

Your 2006 night-sky guide **bonus pullout inside!**

January 2006

Astronomy[®]

Observing, telescopes, origin and fate of the cosmos

Top 10 stories of 2005

SPECIAL ISSUE

Are the new exoplanets more like Earth? • Huygens lands on Titan • Deep Impact slams into a comet
Tenth planet discovered • Cassini explores Saturn's weird moons • Galaxies are now bigger and better

PLUS:

See Saturn at its best until 2029

EXCLUSIVE:

**A field guide to
other worlds** p. 70

**How a fugitive star revealed
the Milky Way's shape**

View the sky's most beautiful nebula

In 2005, a great galaxy got greater. Neighboring M31 in Andromeda is 3 times bigger than previously thought. p. 38

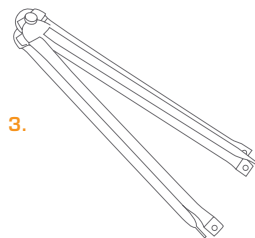
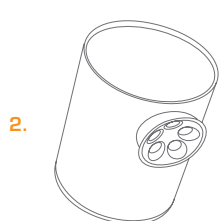
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ON THE COVER

The Andromeda Galaxy (M31) looms large here, but astronomers discovered the galaxy is even bigger than they thought. M31 has a previously undetected disk of stars that triples its size. The scope of this discovery, literally, made it one of the year's most significant astronomy stories. For more, see page 38.

Astronomy

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ZIMASS/MOSAIC IMAGE CONSTRUCTION BY E. KOPAN



NASA/ESA/EPIC KARKOSCHKA (UNIVERSITY OF ARIZONA)



DON GOLDMAN

What makes astronomy big?



Every field has its big stories. With thousands of astronomers decoding the cosmos, millions of objects waiting to be better understood, and lots of telescopes and spacecraft being put to good use, exciting discoveries and big astronomy stories turn up every year. In

"Top 10 astronomy stories of 2005" (page 38), Associate Editor Francis Reddy counts down this past year's most amazing moments — and they were plenty big.

Take, for example, the discovery of a "tenth planet" by Caltech astronomer Mike Brown and his colleagues Chad Trujillo and David Rabinowitz. The distant body was first imaged in 2003 with the 48-inch Samuel Oschin Telescope on Palomar Mountain, California. Designated 2003 UB₃₁₃ and nicknamed "Xena," it was recognized as a distant, icy world when the trio reanalyzed their images January 5, 2005. Because the object is larger than Pluto and 3 times more distant, it has reopened the debate about what makes a planet.

Space missions made 2005 an incredible year for astronomy enthusiasts. On January 14, after 7 years en route to the saturnian system, the European Space Agency's Huygens probe dropped onto the surface of Titan, Saturn's largest moon. This was the first direct exploration of a moon other than our own. As Huygens, slowed by three parachutes, plummeted into Titan's atmosphere, it sampled temperature, pressure, density, and wind speed, giving astronomers a look at this otherworldly place.

While Huygens descended, the mother craft, Cassini, explored the gas-giant planet and other moons from orbit. Looking at Titan from afar, Cassini detected an icy volcano and what scientists suspect is a lake of liquid methane. Surprisingly, Cassini found dusty particles and a thin atmosphere surrounding another saturnian moon, Enceladus. It also found a strange

collection of features, including a long, high ridge, on the moon Iapetus.

Much solar-system exploration these days is driven by the quest to find life, which means tracking water. This means aiming for Mars. On the Red Planet, the twin rovers Spirit and Opportunity continue to return science to Earth. At Meridiani Planum, Opportunity found a salty sea once existed where the rover's tracks now lie. Spirit, exploring Gusev Crater, saw minimal evidence for water until it moved across the plains to the Columbia Hills. There, rocky outcrops suggest abundant groundwater used to flow in the area.

Another spacecraft, NASA's Deep Impact, smashed an 800-pound copper impactor into Comet 9P/Tempel 1 on July 4, creating fireworks. At 23,000 mph, the collision gouged a stadium-size crater into the comet's nucleus. The images the impactor collected as it sped toward its end reveal the most-detailed view of a comet ever. Astronomers were astonished to find the nucleus peppered with ridges, plateaus, and even impact craters.

Other big stories amazed the astronomy world in 2005, and Reddy details each of them. This article is a keepsake you will want to read again and again.

Yours truly,

David J. Eicher
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A lasting vision

Thanks, Mike Reynolds, for “Explore the sky with classic glass” (September 2005). This past summer, my wife and I observed Jupiter through the 8-inch (20 centimeter) 1901 Alvan Clark refractor in the Jordan Observatory on the campus of the University of Maine in



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Orono.] Even with the light pollution on campus, the view was spectacular.

Volunteers open the observatory to the public from 8–10 P.M. on Friday evenings if the sky is clear and the temperature is above 10° Fahrenheit (–12° Celsius). —

WILLIAM A. BREWER, ROCHESTER, NEW YORK

Short-sighted?

I was shocked by the blurb on page 26 of the September 2005 News. It mentions the possible cancellation of the James Webb Space Telescope, due for launch in 2011. With the demise of Hubble on the horizon, and the James Webb slated as its successor, more thorough coverage is warranted.

— **DARYL BEYERS, ATLANTA**

hat’s old is new

I’ve been reading “Making multiverses” (October 2005) with great interest. However, the idea of multiple universes, (while perhaps new in cosmology, is not really new. In the 1920s, mathematician David Hilbert envisioned something called Hilbert space, which contains an infinite number of four-dimensional universes. Eighty years ago, this was just an interesting mathematical idea, but now it appears to have some basis in reality. — **HUGH W. THOMPSON, FLUSHING, NEW YORK**

Rocket science

I enjoyed Bob Berman’s article on rocket propellants, “Ode to kerosene” (October

2005). However, Berman committed one small factual error. He states, “When America first blasted astronauts into suborbital flights inside claustrophobic Mercury capsules, the propellant those Redstone rockets used was, yep, plain old kerosene.”

In fact, while kerosene was employed in the Mercury program, it was for the Atlas booster used in the orbital flights of John

Glenn, Scott Carpenter, Walter Schirra, and Gordon Cooper. The Redstone rockets used for the suborbital flights of Alan Shepard and Virgil G. Grissom were fueled with alcohol. — **ED UTHMAN, HOUSTON**

Several readers pointed this out, and they are correct. One or two others also correctly pointed out that Robert Goddard’s rocket used gasoline, not kerosene. A couple of others wondered whether it was a typo when I said I paid \$963 a gallon for fuel oil. Nope, not a typo, but a joke: It only seems to cost that much. — **BOB BERMAN**

Popular astronomy

I do not share Edward O. Lipton’s gushing enthusiasm for the contributions of Sir Patrick Moore to the astronomy world over the last 40 years (see Letters, August 2005).

To begin with, Moore’s technical discussions of the subject have reduced the field to one of telescopes and trinkets. Nowhere has he really broadened the minds of his young fan club as, say, fellow Brit Stephen Hawking has done.

The former has given us technology, while the latter, cosmology. And of the two, jawZing will, in time, prove the greatest contributor to broadening our field of vision. — **TOM STOPPARD, LONDON**

We welcome your comments. Send letters to Astronomy Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com.

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Death of a star

The Helix Nebula (NGC 7293) in Aquarius shows what the Sun may look like 5 to 6 billion years from now. When a Sun-like star nears the end of its life, it swells into a red giant. The bloated star then puffs off its outer layers, often in two or more stages. The star's blazing-hot core, known as a white dwarf, remains behind. Ultraviolet radiation pouring from the white dwarf causes the gas to glow. Thousands of comet-like filaments in the Helix, embedded along the inner rim of the nebula, point back toward the central star. The strands form where the white dwarf's stellar wind plows into cooler shells of gas and dust ejected earlier. ■







Tangled up in strings

This New Year begins like any other, with scientists still trying to come up with a grand unified theory (GUT). Grand indeed is the noble goal of tying together the universe's fundamental forces. Einstein struggled with it unsuccessfully most of his life, and he wasn't

the only one to have bad-hair days over it. But after listening to PBS specials or reading self-serving books, it appears the race is almost over. The goal is firmly in sight. The GUT-level Messiah: string theory.

According to this theory's advocates, all that's left is ironing out the details. But behind the scenes, many physicists worry. They don't just think string theory (ST) is plain wrong, they fear its existence harms the way science is performed.

Tough words. Let's look deeper.

At heart, physicists are like metaphysicians who suspect everything is connected fundamentally. After all, electricity, light, and magnetism proved to be facets of the same force of electromagnetism; energy and matter proved to be identical, too.

So why quit there? Surely some underlying principle must unite the weak and strong nuclear forces within atoms, plus the puzzling force of gravity, plus electromagnetism itself. Actually, all have been linked under extraordinary circumstances, except for gravity.

String theory includes gravity, too. One-ness at last. ST claims that at the tiniest levels of existence, called the Planck length, more than a million times smaller than a trillionth the size of a proton, vibrating one-dimensional threads of energy link — or loop — in various ways to produce all four forces. It's a simple image, and simple is always good.

Skeptical physicists and theoreticians include Columbia University's Peter Woit, who's an active anti-ST crusader, even though his colleague Brian Greene is argu-

ably the most prominent ST champion. I bet these guys don't play Cat's Cradle with each other in the hallway.

Problem one: String theory won't work in our reality of three dimensions plus the fourth dimension of time. To make it work, its creators had to invent six or seven additional dimensions, which contradicts our own senses and the rest of science. None of these extra dimensions can possibly be tested. They have to be taken on faith.

String theory won't
work in our reality
of three dimensions
plus the fourth
dimension of time.

Problem two: String theory is untestable — no experiment can tell if it's right or wrong.

Problem three: According to Woit, string theory's only prediction (about the strength of the cosmological constant) proved to be incorrect by 55 orders of magnitude. Oops. That's like predicting mice are larger than stars.

Problem four: Those six or seven imaginary dimensions can be tweaked and arranged in so many ways that there is no such entity as "string theory." Instead, there are an almost infinite number of possible final outcomes available.

Problem five: While ST cocreator Michio Kaku of the City College of New York argues ST is "elegant," skeptics see just the opposite: a sewer of swirling ad hoc bandages. All this makes Woit quote physicist Wolfgang Pauli: "It's not even wrong!"

We might wonder why universities and the media would play with strings for so long. Why would grownups invest time with untestable concepts that, after 2 decades, have yet to yield fruit? The partial answer is that these are brilliant people who are having a blast and getting lots of attention. Some of the math has been original and intriguing, although other parts are no more lucid than Bob Dylan lyrics. Play in such imaginary playgrounds for a while, and the fence that separates the real universe from the kind of dreams you get by eating pizza before bedtime gets blurry.

Until recently, science dealt with theories quickly and effectively. They'd be tested. Confirmed ones were kept, wrong ones tossed, flawed ones modified. The process was merciless. But string theorists have managed to concoct dimensions, argue that no testing is possible, and yet somehow enjoy funding year after year.

Peter Woit thinks the main reason is because it's been the only game in town, the hot-button label, the sure way for graduate students to get grants and publicity. But Woit wonders how much longer the media will "waste its time on a perpetual, well-promoted but never-successful investigation of a theory that has no connection with the physical world."

Later this year, Woit's book (among others) will be published, and the whole ball of yarn might begin to unravel publicly. Those in funding positions may finally realize it's time to move on.

In effect, the message will be: That was great fun, guys. But folks are eager to understand our strange universe, and they're tired of grasping at threads. ■

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Researcher. LX200 Enthusiast.

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Q How about optics?

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No Purchase Necessary. The official start date for the *Astronomy* Winter 2005 Sweepstakes is September 23, 2005. Official entry forms are bound in the November 2005, December 2005 and the January 2006 issues of *Astronomy*. The *Astronomy* Winter 2005 Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependants and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and participating sponsors are not eligible to participate.

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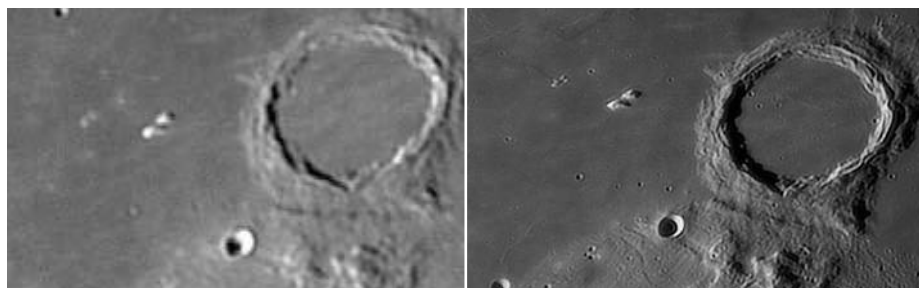
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Power corrupts

Hello, and welcome to our winter star party! We have plenty of telescopes set up around the field. Over by that 12-inch Dobsonian is my friend Eileen. She's talking to a gentleman named Bill, who's new to astronomy. Let's listen in on their conversation:



MORE POWER doesn't always mean more detail, as shown by these two images of the same lunar crater: Archimedes. (LEFT: PAOLO R. LAZZAROTTI; RIGHT)

BILL: How powerful is this telescope?

EILEEN: Well, power isn't as important as optical and mechanical quality, but right now, I'm using a magnification of 60.

BILL: That's all? I just bought a Starblaster 350 60mm refractor at the local department store. It magnifies 350 times!

EILEEN: What does the image look like at that power?

BILL: Well, it's kinda fuzzy.

EILEEN: That's because 350x is way too much power for a 60mm refractor. The highest useful magnification a telescope can produce is about 50x per inch of aperture — the diameter of its light-gathering lens or mirror. Multiply 2.4 by 50x, and you get 120x. According to this rule, my 12-inch scope should handle 600x, but atmospheric conditions rarely allow me to use more than 300x.

BILL: Just how do you figure out a telescope's magnifying power?

EILEEN: It's actually a simple math problem. I take the focal length of my telescope, which is 1,500mm, and divide it by the focal length of the eyepiece. Right

now, it's a 5mm eyepiece. And 1,500 divided by 25 equals 60. If I want to increase my scope's magnifying power, I use a 10mm eyepiece for 150x, and a 6mm eyepiece for 250x.

BILL: Wait a minute. My Starblaster 350 comes with a 4mm "high-power" eyepiece. The telescope has a 700mm focal length. If my math is correct, that's 175x, which is already too much magnification. No wonder I have trouble seeing anything when I use that eyepiece!

EILEEN: So you placed that 4mm eyepiece into your 2x Barlow "booster" lens to get 350x, thinking you'd see much more detail, right?

BILL: Yes, and it was worse! But how do you know so much about the Starblaster 350?

EILEEN: The Starblaster 350 was my first telescope! Want some friendly advice? Lose the 4mm eyepiece, and work with your 20mm "low-power" eyepiece, which will give you 35x. That's enough magnification to see the entire lunar disk, craters and all, Jupiter and its Galilean moons, Saturn's rings, and big,

bright deep-space objects like the Andromeda Galaxy and Orion Nebula. If you want higher power, combine the 20mm eyepiece with your 2x Barlow lens for a comfortable 70x Liew.

So what have we learned from Bill and Eileen's conversation? Power isn't everything.

It's nice that telescopes make distant objects look bigger and closer, and astronomy wouldn't be a fun, exciting hobby if that weren't the case. But bigger and closer won't do any good if you're looking at a 350x blob. Spend time with telescopes, and you realize light-gathering power (image brightness) and resolving power (image sharpness) are far more important than magnifying power.

We could spend more time talking about magnifying power, but astronomy is about *doing*, not *talk*. Go outside and point your telescope toward the Moon — a nice evening target this month from the 3rd (crescent) through the 12th (nearly full). Try all of your eyepieces. Start with the lowest magnification (the biggest "mm" number) to see the whole Moon, and then use higher power to "zoom in" on selected targets. Try the Barlow lens with all eyepieces. You'll find it works just fine with your low-power eyepieces, creating a medium- to high-power eyepiece that's more comfortable to observe with than your high-power eyepiece alone.

Finally, "go for broke" and try the Barlow lens with your highest-power eyepiece. It won't be a pretty sight!

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: We go to the dogs! Clear skies!

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Clear Skies,

Stephen P. Hamilton

Chesapeake, Virginia
36° 45' 28" , -76° 15' 40"

The Triangulum Galaxy (M33) by Steve Hamilton. Meade LX90 8" Schmidt-Cassegrain @ f/3.3.
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During the last 2 months, we've tracked down objects in the constellations Cassiopeia the Queen (November) and her daughter, Andromeda the Princess (December). Both of these figures play pivotal roles in one of the sky's most famous myths: the legend of Andromeda

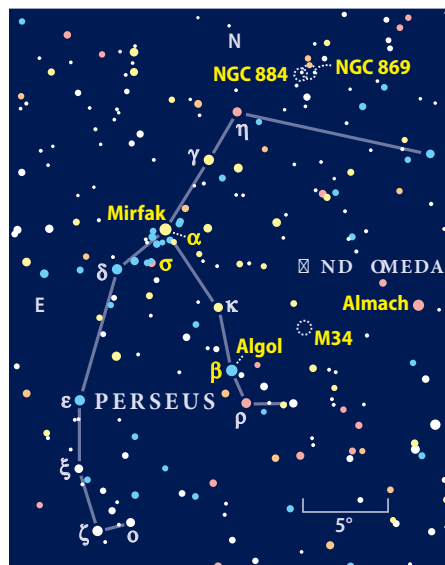
and Cetus. The story goes that Poseidon, Greek god of the sea, punished Cassiopeia for her constant bragging by kidnapping Andromeda and chaining her to a rock by the sea. There, she was to be devoured by Poseidon's viscous sea monster, Cetus.

Just as it looked as though all was lost, our story's hero, Perseus, swooped out of the sky on the back of Pegasus the Flying Horse and saved her.

We can still find Perseus standing protectively over Andromeda in this issue's all-sky map on page 63 — even though trying to see the figure of a mighty warrior is a stretch. Instead, **Perseus** looks more like two jagged arcs of stars curving away from the W pattern of Cassiopeia. The constellation's brightest star, **Mirfak** (Alpha [α] Persei), lies about two-thirds of the way along a line that stretches from Pegasus in the northwest to the bright star Capella in Auriga. Shining at magnitude 1.8, Mirfak is classified as a white giant star and lies about 500 light-years away.

Examining Mirfak through binoculars, we find it surrounded by dozens of fainter stars scattered in small clumps and patterns. While most of the stars appear white or blue-white, a few show slight tinges of yellow or orange. Search for the orange star **Sigma** (σ) **Persei**, one of three stars forming a small triangle south of Mirfak. Also, look for two whitish double stars to the north of Mirfak.

Together, the stars gathered into this football-shape area form the Alpha Persei Association. A stellar association contains mostly hot blue-white and white stars, like



PERSEUS is chock-full of star clusters visible through binoculars.

many open star clusters. Typically, however, the stars in an association gather more loosely than those in open clusters. In the case of the Alpha Persei group, some 50 stars are bound by their mutual — but weak — gravitational field. All lie about the same distance away as Mirfak, having formed from a common cloud of interstellar gas and dust some 50 million years ago.

In Perseus, you'll find two wonderful open star clusters that appear as two overlapping circles on the map. The [r] labels, **NGC 869** and **NGC 884**, correspond to their entry numbers in the *New General Cata-*

logue. You might also know them by their combined nickname, the Double Cluster.

Even from suburban skies, your unaided eyes can see the Double Cluster as a small, faint smudge of light between Perseus and Cassiopeia. Find them through your binoculars by extending a line from Gamma (γ) Cassiopeiae, the center star of the W, through Delta (δ) Cas and continuing east.

If you maintain a straight course, you will see both clusters as two knotty knots of stars. The one closer to Cassiopeia, NGC 869, appears more densely packed. Most of the stars look either white or blue-white, but you might notice a few yellow and orange stars as well. To make subtle star colors stand out more vividly, defocus your scope slightly.

Finally, let's take aim at the open cluster **M34**. You'll find it about halfway between the stars Gamma (**Almach**) in Andromeda and Beta (β) (**Algol**) in Perseus. A great target for binoculars, M34 covers an area as large as the Full Moon. Look for the brightest of its 100 stars twinkling in the hazy glow of fainter background stars.

These are just a few of the objects awaiting your binoculars tonight. Be sure to stop by Astronomy.com this month for information about other Perseus targets, including tips for observing the star Algol, the sky's most famous eclipsing binary star.

Let me close for now by extending my best to you and yours for a very happy new year. May we all enjoy many clear nights throughout 2006. And if you have a favorite binocular target, I would love to hear about it and possibly include your observations in a future column. Send your thoughts via e-mail to phil@philharrington.net.

Next month, we visit the grandest constellation of all! Till then, remember: Two eyes are better than one! ■

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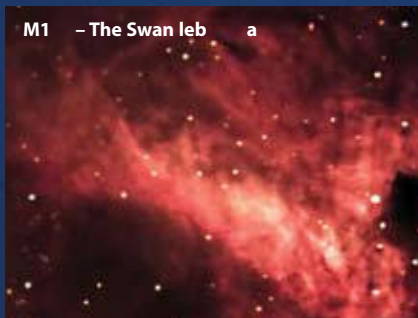
NGC3132 – The Southern Ring Nebula



M64 – The Black Eye Galaxy



M1 – The Swan Nebula



NGC6543 – The Cat's Eye Nebula



NGC3132 by *Charles Parker* – Souahland, New Zealand
@ f/10, 15 x 20 seconds.

M64 by *George Lilley* – Warner Robins, GA
@ f/3.3, 30 x 1 minute.

M17 by *Matt Taylor* – Palmdale, CA
@ f/3.3, 5 x 4 minutes.

NGC6543 by *Alonzo Villarreal* – Merrillville, IN
@ f/10, 35 x 1 minute.

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Deluxe Equatorial Mount



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The Reviews are In: "A telescope mount for the 21st century" Astronomy magazine, November 2005

- ◆ "The Star Book is so easy to operate it flirts with user-interface perfection ..."
- ◆ "As it stands now, the Sphinx is by far the easiest-to-use go-to mount."
- ◆ "Those interested in imaging should give this mount consideration."
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- ◆ "More good news: The mount is terrific."
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Recommended Accessories

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news 01

Deep Impact serves up food for thought, "Xena" sidekick found, Japan's Hayabusa spacecraft meets asteroid Itokawa, Hubble stops by a galactic zoo

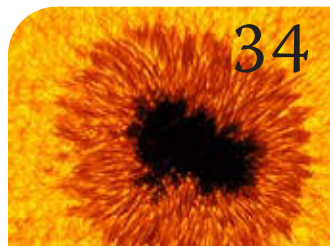


False color
38,500 miles from Hyperion

Visible light
20,000 miles away

NASA/JPL/SSI

BEEHIVE MOON. Cassini returned the best-ever images of Saturn's battered moon Hyperion. The spacecraft buzzed the 165-mile-wide (266 kilometers) moon September 26, 2005, passing within 310 miles (500 km) of the surface.



34

Hyperion scarred by heavy bombardment

NASA's Cassini spacecraft capped a busy year at the ringed planet with a spectacular image of Saturn's peculiar moon Hyperion. The spacecraft swept past Hyperion and Tethys, another moon, September 26, revealing never-before-seen features on both bodies. But Hyperion's spongy, crater-riddled visage took scientists by surprise.

Cassini passed within 310 miles (500 kilometers) of Hyperion. The moon actually has a reddish tint, but false-color views, such as the one above, perhaps reveal color differences that indicate different surface materials. The image on the left, taken when the probe was still 38,500 miles (62,000 km) from its closest encounter, combines images taken through infrared, green, and ultra-

violet filters. Scientists enhanced the composite to make subtle color variations across the small moon's surface more apparent.

A bluish rim and central mound suggest an ancient crater almost as large as the 165-mile-wide (266 km) moon itself. The dark material filling many craters is unknown, but others have bright rims, so the substance may be a veneer only tens of feet thick. On steep slopes, landslides have nearly eliminated some craters.

Although Hyperion is the smallest of Saturn's major satellites, it's the largest irregularly shaped moon studied so far. This flyby was the only close look at Hyperion scheduled in Cassini's 4-year prime mission. — FRANCIS REDDY

30 MIT astrophysicists find new cosmological clue

31 First spacecraft to Pluto

34 New camera zooms in on the Sun's surface

37 Earth's crust buckles under Amazon's weight



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New cosmological clue

Astrophysicists at Massachusetts Institute of Technology's Haystack Observatory in Westford, Massachusetts, have detected deuterium's radio signature for the first time. They measured the deuterium-to-hydrogen ratio as 23 parts per million, which is close to the Wilkinson Microwave Anisotropy Probe prediction of 25 parts per million.

The amount of deuterium detected puts a constraint on the photon-to-baryon ratio. This ratio is related to the amount of matter in the early universe, therefore giving cosmologists clues about the nature and abundance of dark matter.

Deuterium is also known as "heavy hydrogen." While hydrogen has one proton and one electron, deuterium has the same plus one neutron.

The astrophysicists detected the signal at 327 megahertz, which corresponds to a wavelength of 92 centimeters. Deuterium's 92cm signature emission line is similar to hydrogen's 21cm line.

Astronomers can recognize hydrogen's presence if the 21cm emission line is visible. Similarly, they can say deuterium must be present if they see an emission with a 92cm wavelength.

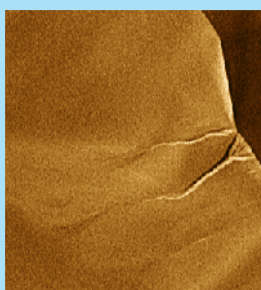
Deuterium's signal is difficult to detect because there is only about one deuterium atom for every 100,000 hydrogen atoms, and deuterium's spectral lines lie close to hydrogen's in the optical spectrum. However, the elements' emission lines can be far enough apart in the radio spectrum to distinguish between the two.

The scientists observed opposite the galactic center from June 29, 2004, to April 29, 2005. Their findings were published in *The Astrophysical Journal Letters* (September 1, 2005). — **LIZ KRUESI**



BRUCE WHITTIER, HAYSTACK OBSERVATORY

STRENGTH IN NUMBERS. The array at Haystack Observatory consists of 24 stations, each with 24 crossed antennae.



NASA/JPL/MS55

NOW YOU SEE IT. New gullies appeared while Mars Global Surveyor watched.

Lines in the sand

Mars Global Surveyor discovered new gullies that formed on a sand dune west of Mars' Hellas Basin between July 2002 and April 2005.

Researchers think dune gullies form when buried patches of dry ice suddenly sublime, causing overlying sand to sink into the area the ice occupied.

The longest of the new gullies measures about half a mile (850 meters) long, as much as 130 feet (40m) wide, and just a few yards deep. — **F. R.**

A giant surprise

Giant stars with planets often have smaller amounts of heavy elements than the Sun, say astronomers in the United States and Germany.

Since first discovering an extra-solar planet around a Sun-like star, 51 Pegasi, 10 years ago, astronomers have noticed most planet-bearing stars contain large amounts of elements heavier than helium — called metals.

Now, Simon Schuler (Clemson University) and his colleagues say giant stars obey a different rule. They studied a planet-bearing orange K-type giant named HD 13189, and found the star's

metal content is only 26 percent of the Sun's.

Schuler's team looked at metallicities of other planet-bearing giant stars, only seven of which are known. All contain fewer metals than most planet-bearing main sequence stars.

Perhaps, say scientists, stars more massive than the Sun form planets in a different manner than the Sun. But to confirm this, astronomers must discover planets around more giant stars. The team's work appeared in the October 20, 2005, *Astrophysical Journal Letters*.

— **KEN CROSWELL**

Deep Impact's unexpected results

When NASA's Deep Impact probe hit Comet Tempel 1 July 4, data confirmed scientists' ideas about comet structure while providing some new food for thought.

The Spitzer Space Telescope observed the resulting dust cloud. It detected clay and carbonates in addition to the expected silicates. Carbonates form only in the presence of liquid water, which makes scientists wonder how

a frozen body could have made them.

Tempel 1 also appears to have craters. Gravity weakly binds together the fine dust grains that comprise the comet's nucleus. So how such craters formed is unclear.

Infrared studies show the nucleus is extremely porous. This allows the surface to heat and cool rapidly. The icy interior, however, is well shielded, which helped keep the



NASA/JPL-CALTECH/UMD

DIRECT HIT. The Deep Impact probe returned new data on comet structure.

comet's ice in a deep freeze since the solar system's earliest days.

— **LAURA BAIRD**



New Horizons set for wild ride

The first spacecraft destined for Pluto and beyond — New Horizons — will launch sometime between January 11 and February 14. The probe's electrical power comes from heat generated as radioactive plutonium decays. This energy allows New Horizons to conduct its science from a location that gets 1,000 times less sunlight than Earth.

To fling the probe from Earth fast enough for a “reasonable” travel time — about 3.5 billion miles (5.6 billion kilometers) in 15 years — NASA will fit an Atlas V booster with the maximum number of strap-on solid-fuel boosters. This powerful configuration, which has never been flight-tested, will deliver the fastest-ever Earth-departure speed.

The spacecraft will swing past Jupiter — 390 million miles away (630 million km) — in 13 months. The previous record: Ulysses, which sped from Earth to Jupiter in 16 months. New Horizons may reach a maximum speed of 130,000 mph (180,000 km/h) during its journey.

The combination of a possible launch mishap with this untried rocket power and its potentially hazardous cargo (plutonium is dangerous both as a radiation source and as a poisonous heavy metal) has drawn more scrutiny than previous Atlas V launches. More than half a dozen variations of the



TO THE GREAT UNKNOWN. In July 2015, the first spacecraft to visit Pluto will give us a look at the ninth planet and its moon. If all goes well, New Horizons will fire its engine and cruise toward a new target — a Kuiper Belt object — a few weeks after the Pluto encounter.

Atlas V booster have flown so far, all successfully. Protective packaging of the plutonium puts the chance of spillage at less than 1 in 300.

The last plutonium spill from a space probe came from Russia's Mars-96 mission, in November 1996. Small packets of the material scattered across the Andes Mountains after the probe's upper stage failed. Officials in Moscow and Washington insisted the fragments had fallen harmlessly into the deep Pacific Ocean. However, weeks later, U.S. military space-tracking officials confirmed eyewitness reports claiming

the fireball crossed the coast heading inland. People in the actual impact area were never warned.

Fortunately, New Horizons has a great chance for a successful launch, and a better chance for an effective flight. After visiting Pluto and its moon Charon, the probe will be directed toward one or more of the recently discovered Kuiper Belt “ice-teroids,” a few more years of flight time away. Powered by plutonium (the last leftovers in the U.S. space cupboard), the probe's instruments and radio will spend a decade or more exploring trans-plutonian space. — **JAMES OBERG**



NASA/ESA/STScI/J. PARKER, ET AL.

ICY ASTEROID. Texas-size Ceres may be a mini-planet with a water-rich mantle. This contrast-enhanced false-color composite of Ceres is made from Hubble Space Telescope images taken in visible and ultraviolet light.

An icy interior for asteroid Ceres?

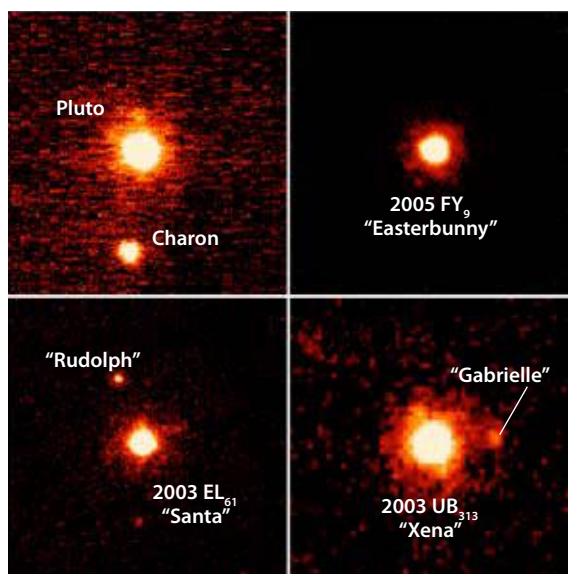
The largest main-belt asteroid may have an icy mantle beneath its surface. Located near the middle of the belt, Ceres is the largest such body at about 592 miles (952 kilometers) across.

A team of astronomers led by Peter Thomas of Cornell University found Ceres' shape is determined by hydrostatic equilibrium, in which the weight of the overlying material determines the pressure at any point within the body.

The equatorial region of any body that spins fast enough bulges outward. Instead of looking like a perfect sphere, the object looks “flattened.”

Ceres has a mean density of about 2.1 grams per cubic centimeter (roughly twice that of water). A uniform body of this density should have a polar radius about 23.8 miles (39.7 km) smaller than the equatorial radius. Ceres' polar radius is only 19.6 miles (32.6 km) smaller. This is strong evidence its interior consists of different layers. In fact, the smaller amount of flattening indicates the presence of a mantle and a core.

The team developed computer models of Ceres' interior using available data on the asteroid and found Ceres has a rocky core and could have an icy mantle as thick as 77 miles (124 km), amounting to about one quarter of its mass. — **BILL COOKE**



MICHAEL BROWN

MOON TRIO. In addition to Pluto, three of the Kuiper Belt's largest objects — shown here at the same scale in images from the 10m Keck II Telescope — have moons.

The tenth planet has a sidekick

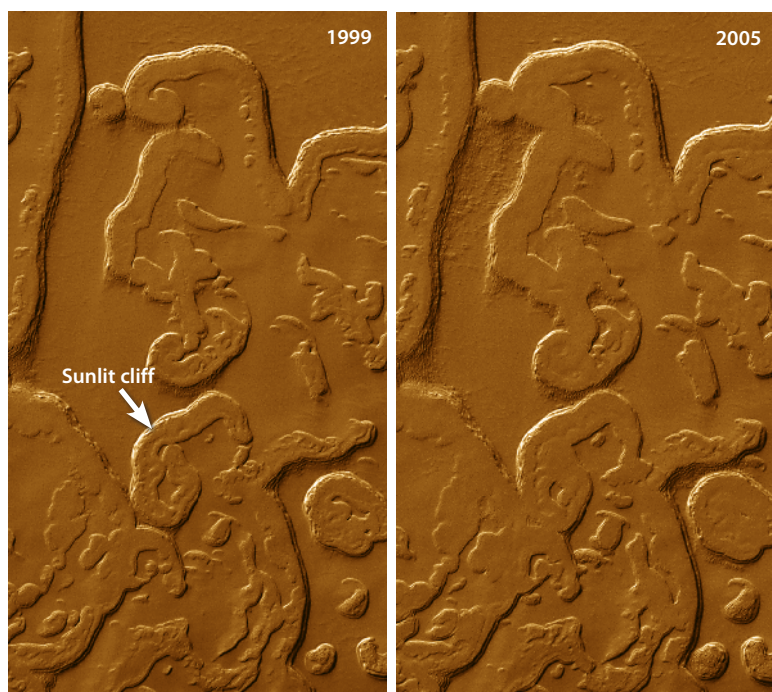
First, there was 2003 UB₃₁₃, a world perhaps 1,677 miles (2,700 km) wide — about 20-percent larger than Pluto. It's now some 9 billion miles (14 billion km) from the Sun, completing one orbit in more than 550 years.

Caltech's Michael Brown announced the object's discovery July 29, dubbing it the tenth planet due to its size and giving it the playful-but-unofficial name "Xena."

Now, says Brown, Xena has a moon. Brown and his team found the satellite September 30, 2005, while observing with the Keck II Telescope's new adaptive optics system, which compensates for atmospheric blurring. The moon, which Brown

nicknamed "Gabrielle" after the fictional Xena's sidekick, is only about 155 miles (250 km) across — about 9-percent Xena's size. Astronomers estimate the moon completes one orbit around Xena every 14 days or so.

The discovery is important because, by scrutinizing Gabrielle's motion, astronomers will be able to determine Xena's mass. Brown says Gabrielle, Pluto's moon Charon, and the moon of another object (2003 EL₆₁) may have formed much like our own Moon did. Planetary scientists think a giant body slammed into the early Earth, throwing out a cloud of debris that came together to make the Moon. — **F. R.**



NASA/JPL/MSS

Martian features disappear

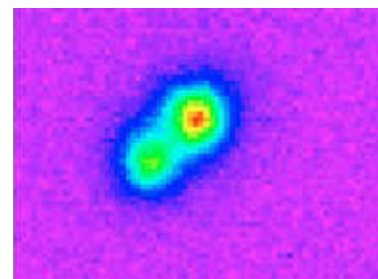
SHRINKING MESAS. Mesas of dry ice at the martian south pole have been retreating by about 10 feet (3m) per Mars year since Mars Global Surveyor arrived in 1999. These images compare the same region in 1999 and 2005. Mars seems to be in a warm spell. Dry ice turns to gas on the mesas' sides, but no new ice is being deposited. Over time, the polar pits will merge into plains, mesas will shrink into buttes, and buttes will vanish forever. — **F. R.**

100 billion brown dwarfs

Brown dwarfs may rival the number of all normal stars in our galaxy. Astronomers at Arizona State University used near-infrared data to find 28 brown dwarf stars as red as those with the coolest spectral types, L and T.

Extrapolating from the number of brown dwarfs they discovered, Russell Ryan and his colleagues estimate the galaxy has roughly 100 billion L- and T-type dwarfs. This is comparable to the total number of all other stars astronomers estimate the Milky Way contains.

Despite their impressive number, brown dwarfs add little weight to the galaxy; Ryan's team estimates they contribute roughly a billion



GEMINI OBSERVATORY/AURA

CLOSE DWARFS. Several brown dwarfs may lie even closer to Earth than these two, which orbit Epsilon Indi, a star only 11.8 light-years away.

solar masses to the Milky Way — only 0.1 percent of the galaxy's total.

Their work is published in *Astrophysical Journal Letters* (October 1, 2005). — **K. C.**

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photographer to lock up the mirror and open the shutter at night to sharply focus subjects before the image is captured, in either 5x or 10x magnification.

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Short GRBs explained

Short gamma-ray bursts (GRBs) are the result of two neutron stars merging or a black hole eating a neutron star, say astrophysicists.

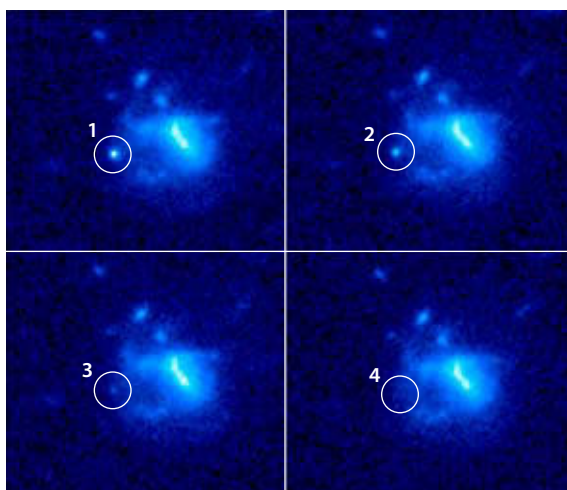
Scientists classify GRBs in two groups: short (lasting less than 2 seconds) and long (more than 2 seconds). For years, scientists have known long GRBs occur when massive stars collapse into black holes, even though they didn't know what produces short GRBs. Because the bursts last only a short time — on the order of tens of milliseconds — telescopes and satellites could not, until now, move quick enough to pinpoint a short GRB's location.

NASA's High Energy Transient Explorer (HETE) detected a short GRB July 9, 2005 — named GRB 050709. Both Chandra and NASA's Swift Satellite observed the afterglow. Hubble and ground-based telescopes found an optical source at the same location as the X-ray source, thus making the first optical observation of a short GRB's afterglow.

Swift detected two other short GRBs May 9, 2005, and July 24, 2005 — GRB 050509b and GRB 050724, respectively. Compared to long GRBs, these short bursts are closer: 2 to 3 billion light-years compared to up to 13 billion light-years. Astrophysicists also analyzed the bursts' brightnesses and found them to be about 1,000 times less energetic than long GRBs.

All three short bursts are located on the outskirts of their host galaxies, "just where old merging binaries are expected," says George Ricker of MIT, and HETE's principal investigator. Long bursts occur in the dense star-forming areas of galaxies, where massive stars collapse.

The short-GRB findings are in the October 6, 2005, issue of *Nature*. — L. K.



FADING AFTERGLOW. GRB 050709 (circled) sits to the left of its host galaxy and faded quickly. The images were taken 5.6 (1), 9.8 (2), 18.6 (3), and 34.7 days (4) after the burst.



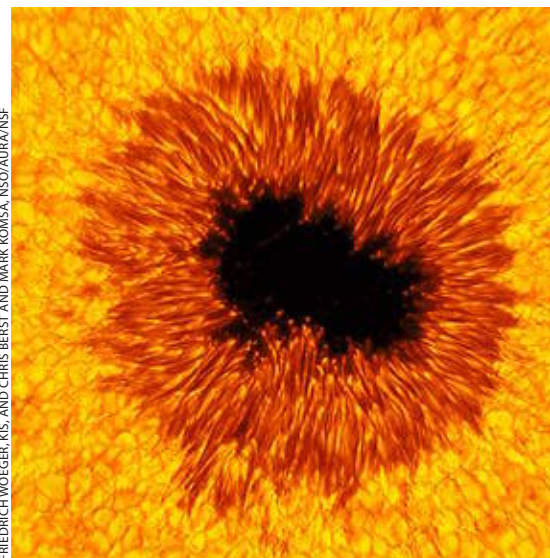
UP-CLOSE ASTEROID. Hayabusa snapped this view of Itokawa September 12, 2005.

Hayabusa meets asteroid

Japan's Hayabusa space probe arrived at asteroid Itokawa September 12, 2005. Itokawa looks like it formed when two large masses collided at slow speed and fused together — our first glimpse of a "rubble pile" asteroid. Itokawa spins once on its axis every 12.1 hours. It's about 1,970 feet (600 meters) long by 980 feet (300m) wide.

Hayabusa is expected to collect dust samples, which it will return to Earth in summer 2007.

JEREMY MGOVERN



COOL VIEW. New camera zooms in on the Sun.

Details on the Sun

Sunspot 10810 crackles with energy in this image taken with the National Science Foundation's Dunn Solar Telescope in Sunspot, New Mexico. A new high-resolution CCD camera attached to the telescope's adaptive optics, which counter the blurring effects of Earth's atmosphere, captured this sight. The dark umbra and lighter, fluted penumbra are cooler than the surrounding gas. The image spans about 25,000 miles (41,000 km), or 3 times Earth's diameter. — L. B.

Giant scope ready for work

Five years after construction began, the South African Large Telescope (SALT), a cutting-edge instrument at the outskirts of the Kalahari Desert in South Africa, is now operational.

The scope boasts a primary mirror array 32 by 36 feet (10 by 11 meters), making it the largest telescope in the Southern Hemisphere.

Each of its 91 mirrors contains three edge sensors that

maintain the segment's position with neighboring panels. This unique design delivers a light-gathering power that rivals the world's largest optical scopes; SALT could detect a candle flame on the Moon.

Planned targets include the Large and Small Magellanic clouds to better understand galactic evolution. Ultraviolet observations using its Prime Focus Imaging



SALT SEES LIGHT.

Open star cluster NGC 6530 in the Lagoon Nebula was among SALT's first targets.

Spectrograph (PFIS) should provide important insights. SALT is supported by 11 scientists from around the world. — L. B.

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HUBBLE ZOOMS IN ON THE MOON. The Hubble Space Telescope's resolution and sensitivity to ultraviolet light will help scientists study mineral variations within the lunar crust — oVe of the many critical steps toward human lunar exploration.



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BLUE BEAUTY NGC 1350 is part of a cluster.

Galaxy stands out in a crowd

NGC 1350 is about 130,000 light-years across, slightly larger than our Milky Way, and lurks 85 million light-years away. Light from young and massive stars tints its spiral arms blue. Dust creates the dark tendrils in the galaxy's central region. The galaxy's outer parts are so tenuous, we can see many background galaxies through them. The European Southern Observatory's Very Large Telescope on Cerro Paranal in the Chilean Andes acquired this image. — F. R.

A galaxy at the frontier

A team led by Bahram Mobasher of the Space Telescope Science Institute and the European Space Agency found a giant galaxy lurking in the Hubble Ultra Deep Field (HUDF).

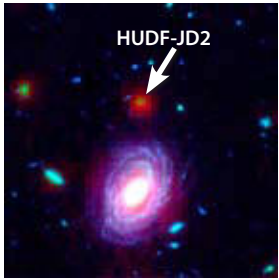
"This galaxy, named HUDF-JD2, appears to have 'bulked up' amazingly quickly, within the first few hundred million years after the Big Bang," Mobasher says. "It made about 8 times more mass in stars than is found in our own Milky Way today, and then, just as suddenly, it stopped forming new stars."

The object is invisible on Hubble's optical images,

but faintly appears on its near-infrared images. But HUDF-JD2 is much more prominent on longer-wavelength infrared views from the Spitzer Space Telescope.

The team members were unable to measure the object's redshift, which they believe is between 6 and 7.5. The astronomers instead estimated HUDF-JD2's distance indirectly by looking at its energy at different wavelengths.

It's the best distance astronomers will get for HUDF-JD2 for some time. "There's no real prospect of getting a more accurate distance with current facilities," says team member Richard Ellis from Caltech. "This object is at the frontier. It's telling us there's a rich amount of astronomy at earlier times in cosmic history." — F. R.



NASA/ESA/B. MOBASHER

FAR-OUT GIANT. HUDF-JD2 shows up as a red dot in this combined view from the Hubble and Spitzer space telescopes.

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NASA, ESA AND THE HUBBLE HERITAGE TEAM (STSC/AURA)

GALAXIES GALORE. Hubble goes deep.

Hubble views a zoo

This deep look into the universe has a rich assortment of unusual galaxies, from majestic spirals to red blobs. A handful of Milky Way stars are also present, as shown by their diffraction spikes. Hubble's Advanced Camera for Surveys snapped this "bonus" image while a different camera took images for a science program. This image is one of Hubble's longest exposures — it took some 40 hours to complete. — **L. K.**

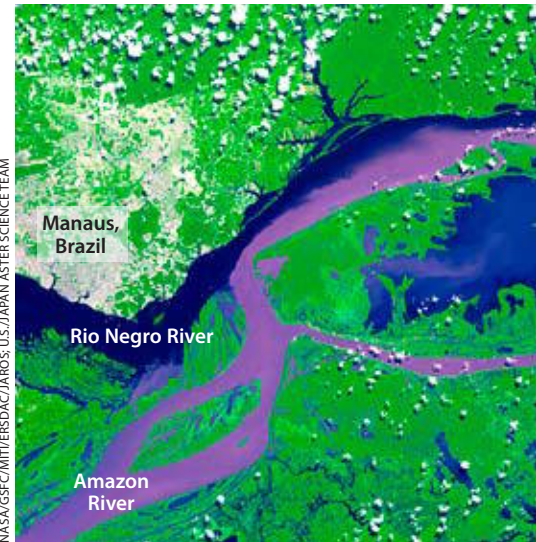
Scientists take the Amazon's pulse

A team led by Michael Bevis at Ohio State University in Columbus has measured how seasonal river floods compress surrounding terrain. A global-positioning-satellite station in Manaus, Brazil, near the confluence of the Amazon and Rio Negro rivers, rises and falls each year by as much as 3 inches (75mm).

This is the largest crustal oscillation observed to date on Earth — and more than twice that predicted for the region.

The greatest compression occurs exactly when the Amazon floods. "This suggests that we are observing, for the first time, a purely elastic response to changes in the weight of a flowing river system," the team reports in *Geophysical Research Letters* (August 24, 2005).

The area covered by the Amazon and its tributaries more than triples in the course of a year, expanding up to 135,000 square miles (350,000 square km). — **F. R.**



NASA/GSFC/MITI/ERSDAC/JAROS, U.S./JAPAN ASTER SCIENCE TEAM

UPS AND DOWNS. Near Manaus, Brazil, Earth's crust oscillates in response to the mighty Amazon's weight. The city is located where the sediment-laden Amazon meets the dark, tannin-rich Rio Negro.

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The Helix Nebula (NGC 7293). Image by Steve Hamilton using his Meade 8" LX90 and a Meade f/3.3 focal reducer. Meade DSI-PRO. LUM=28 x 4 min, R=12 x 4 min, G=12 x 4 min, B=6 x 4 min. Autoguided with DSI.

Top 10 astronomy stories of 2005

This past year, spacecraft explored two planets and touched a comet, while astronomers puzzled over an errant asteroid, larger galaxies, and a titanic explosion in space. /// BY FRANCIS REDDY

The Cassini spacecraft opened a year bustling with spacecraft activity. It flew past Saturn's moon Iapetus and Titan, returning new images of these very different mini worlds. The Cassini-dispatched Huygens probe dropped into Titan's atmosphere, giving us a glimpse of a frigid landscape both alien and familiar.

Robot rovers continued their amazing Mars treks, while another spacecraft slammed into a comet. Meanwhile, earthbound astronomers crowned a newfound ice world as the tenth planet claimed the first image of a world beyond the solar system, and studied a record-breaking deep-space explosion.

As *Astronomy* editors ranked the most significant events of the past 12 months and offer this countdown through the year's top stories.



ASTRONOMY HAD a busy and diverse year in 2005. A sampling: Galactic neighbor M31 is much larger than previously thought. Space shuttle Discovery returned to orbit, testing NASA improvements. The Huygens probe settled onto Saturn's icy moon Titan.

M31: TONY HALLAS; SHUTTLE: NASA; HUYGENS ON TITAN: MICHAEL CARROLL FOR ASTRONOMY

10 Blast from beyond

The wave had traveled for 50,000 years, and on December 27, 2004, it swept over Earth. That's when satellites detected the brightest outburst beyond our solar system ever recorded. The original explosion gave off more energy in a tenth of a second than the Sun emits in 100,000 years.

The blast originated from a highly magnetized neutron star called a magnetar. The object, designated SGR 1806–20, lies 50,000 light-years away in the constellation Sagittarius, on the other side of our galaxy. The remnant of a massive star that exploded as a supernova, a neutron star packs our Sun's mass and more into a ball less than 15 miles (24 kilometers) wide. A rare breed of neutron star, a magnetar sports magnetic fields 1,000 times stronger than normal. Of the 1,500 neutron stars astronomers have cataloged, only a dozen rank as magnetars.

"This might be a once-in-a-lifetime event for astronomers, as well as for the

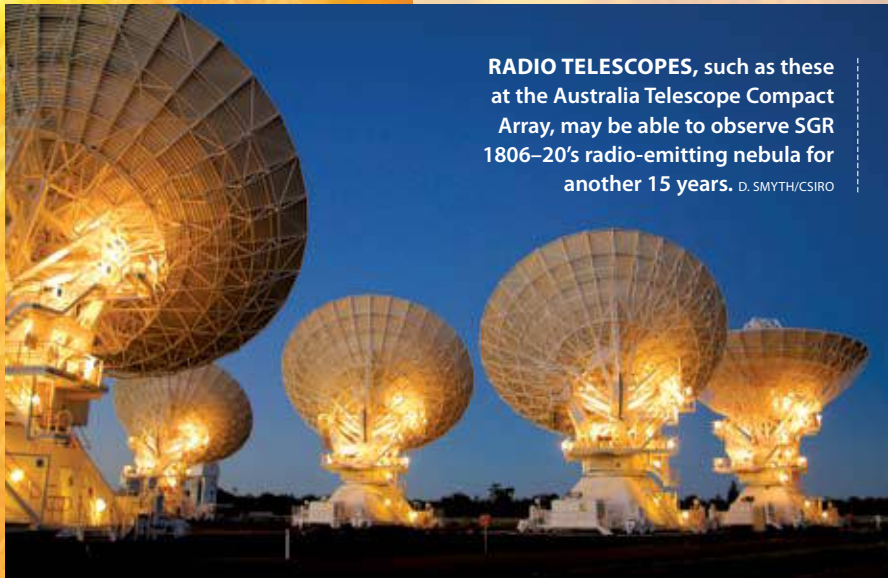
neutron star," says David Palmer of Los Alamos National Laboratory, who analyzed the flare using NASA's Swift satellite. "We know of only two other giant flares in the past 35 years, and this December event was 100 times more powerful."

The radiation struck Earth as a spike of gamma rays, followed by a tail of X rays and radio waves. The Russian satellite Coronas-F was behind Earth at the time and unable to detect the outburst directly, yet it picked up radiation reflected off the Moon. The sudden surge of gamma rays heated Earth's ionized upper atmosphere and caused it to expand. A dozen amateur astronomers who were monitoring radio waves passing through the ionosphere noticed and reported this disturbance.

Scientists believe the intense magnetic fields within a magnetar become twisted, straining its outer crust, which eventually fractures. The result is a sudden rearrangement of the external magnetic field and an enormous outpouring of energy — a magnetar flare. As energetic matter violently collides with surrounding gas, it creates a glowing, expanding, radio-emitting bubble. Ground-based radio observatories in the United Kingdom, India, the Netherlands, Australia, and the United States detected this radio afterglow and showed the bubble to be expanding at about a quarter of the speed of light.

According to Bryan Gaensler of the Harvard-Smithsonian Center for Astrophysics, who studies the radio nebula using the Very Large Array in New Mexico, astronomers may be able to monitor the afterglow until 2020.

Francis Reddy is an associate editor of *Astronomy*.



RADIO TELESCOPES, such as these at the Australia Telescope Compact Array, may be able to observe SGR 1806–20's radio-emitting nebula for another 15 years. D. SMYTH/CSIRO

MAGNETAR SGR 1806–20 BLASTS gamma rays and radio waves across the galaxy after a star-quake ruptures its surface. The intense magnetic field constrains the blast to a tight belt. DON DIXON

Exoplanet surprises



EVENING FALLS gradually on a moon orbiting the Jupiter-like planet at HD 188753. Here, an artist imagines the scene when the bright, close primary star sets behind a mountain and the remaining stars illuminate the terrain. NASA/JPL-CAL ECH

Although astronomers claim to have discovered more than 155 extrasolar planets — worlds beyond those in our solar system, circling stars other than our Sun — no one expected to see one imaged so soon. Yet, in May, a team of American and European astronomers announced they had done just that.

European Southern Observatory astronomer Gaël Chauvin led the team that imaged a 5-Jupiter-mass object around 2M1207A, a 25-Jupiter-mass brown dwarf. The images were actually taken in 2004, but the team needed additional observations to show the “giant-planet candidate” actually was traveling through space with the brown dwarf.

The object, now called 2M1207b, displays a spectrum showing the presence of water vapor, indicating cool temperatures. This and other measures suggest its mass is at most 5 times that of Jupiter.

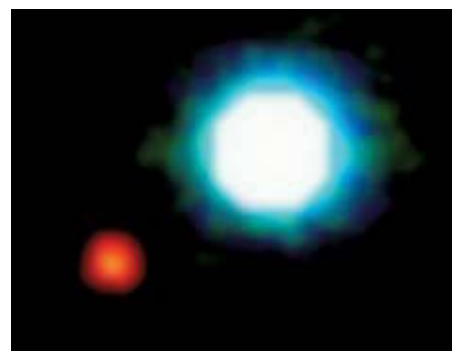
The University of Arizona’s Glenn Schneider observed the system with the Hubble Space Telescope. He estimates 2M1207b lies 170 light-years away

means the separation between 2M1207b and its brown dwarf is 40 times that between Earth and the Sun. The planet’s “year” is 1,500 Earth-years long, so any motion astronomers detected between the planet and its primary would mean they weren’t bound together. But 2M1207b challenges ideas of planetary formation.

“It’s a planetary mass,” Schneider says, “but is it a planet?”

“The fact that it’s in orbit around a brown dwarf set some people aback,” says Alan Boss, a planet-formation theorist at the Carnegie Institution of Washington. “But more importantly, I think, is the fact that the object is only 5 times less massive than its primary. This looks like a classical little binary star.”

He suggests the companion should be called a sub-brown dwarf. “There actually are objects we’ve seen in isolation in star-forming regions that seem to have masses as low as 5 to 10 Jupiters,” Boss explains. “Placed around a star, we’d be happy to call such objects planets, but they formed differently, in isolation, like stars.”



THE BROWN DWARF 2M1207A has a smaller, cooler companion. European astronomers are calling this the first image of an exoplanet, but others think the object is rightly called a subdwarf star.

Other surprises awaited planet-hunting astronomers. In June, Geoffrey Marcy at the University of California, Berkeley, announced discovery of a “super-Earth” orbiting Gliese 876. The star lies 15 light-years away in Aquarius, has about a third the Sun’s mass, and possesses two larger, Jupiter-size worlds. It’s the smallest star known to harbor planets.

“This is the smallest extrasolar planet yet detected and the first of a new class

Continued on next page



NSF/TRENT SCHINDLER

8 An asteroid among us

EXTREME HEAT and reddish light are among the few things certain about the “super-Earth,” illustrated here, found orbiting the M-class dwarf Gliese 581.

of rocky terrestrial planets,” says team member Paul Butler of the Carnegie Institution in Washington. “It’s like Earth’s bigger cousin.”

The team believes the planet has a minimum mass of 5.9 Earths and is 7.5 times Earth’s size. The super-Earth orbits just 2 million miles from its star — or about 18 times closer than Mercury orbits our Sun — and whips around its star every 1.94 days. The super-Earth’s surface temperature must be super hot, likely between 400° and 750° Fahrenheit (200° and 400° Celsius).

“I think what we are seeing here is something that’s intermediate between a true terrestrial planet like the Earth and a hot version of the ice giants Uranus and Neptune,” says team member Greg Laughlin of Lick Observatory.

And in July, Maciej Konacki, a planetary scientist from the California Institute of Technology, announced finding a planet in the triple-star system HD 188753, which lies 149 light-years away in Cygnus. It’s the first planet found in a three-star system. “Planets from complicated stellar systems will put our theories of planet formation to a strict test,” Konacki says. He found the planet by surveying close multiple-star systems with the 10-meter Keck Telescope at Mauna Kea, Hawaii.

The tristar planet orbits the system’s primary star just 3.5 days. At a comparable distance between the Sun and Saturn — about 888 million miles (1.43 billion km) — separates the primary star from the others. An observer on a moon orbiting this Jupiter-size planet would see a sky with three bright suns.

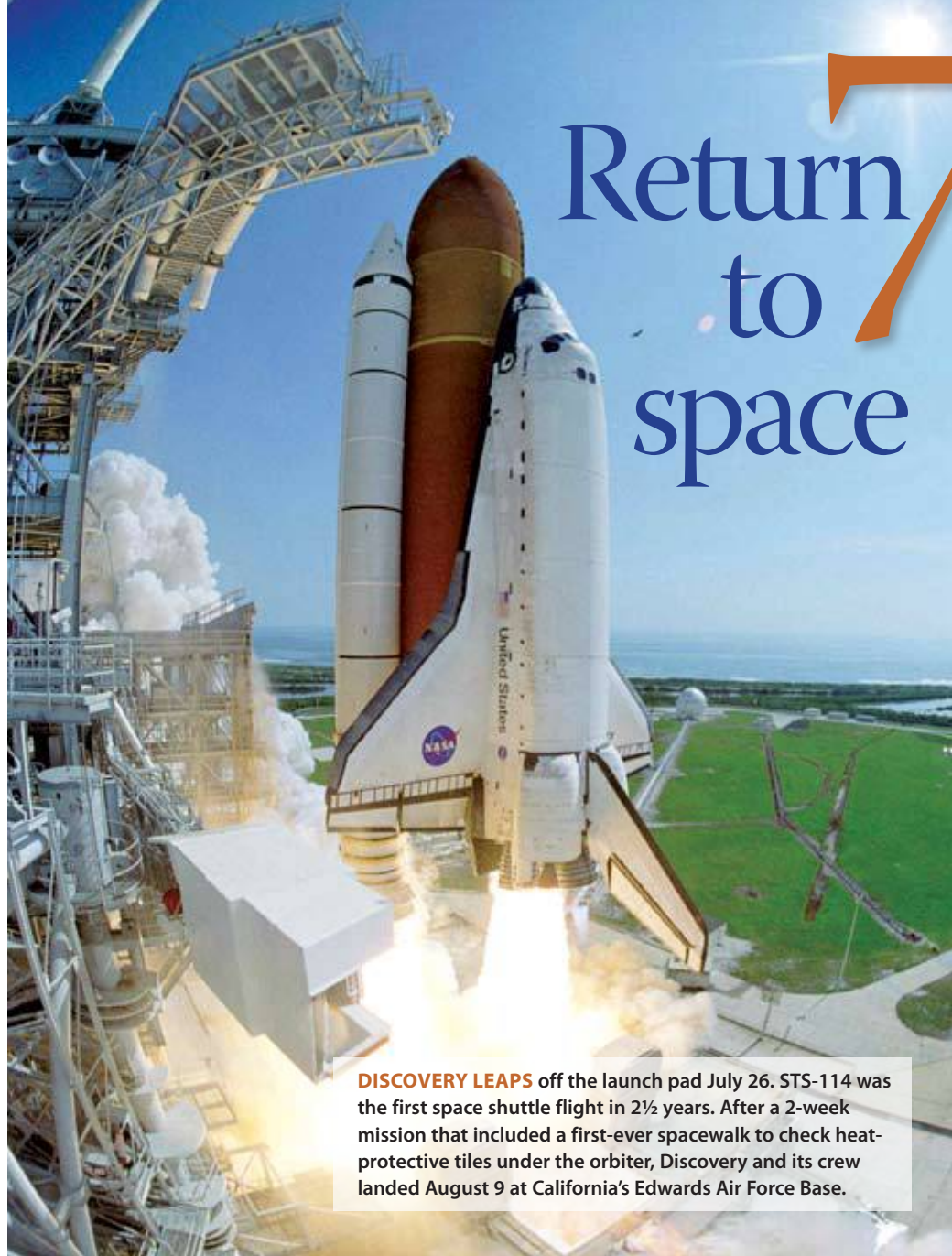


A YARD-LONG white gouge (center) marks where the largest piece of insulating foam separated from the shuttle's external tank during Discovery's ascent.

Grounded since the February 2003 Columbia disaster, the U.S. space shuttle program returned to space with STS-114 July 26. As shuttle Discovery leaped into orbit, pieces of insulating foam — including a yard-long chunk nearly the size of one that struck and doomed Columbia — popped off the shuttle's external tank. The incident marred an otherwise perfect mission to restock and upgrade the International Space Station.

NASA's new administrator, Michael Griffin, confirmed by the U.S. Senate in April, had earlier stated that the first two shuttle flights should be seen as test flights. The integrity of foam insulation and the performance of new camera equipment installed to detect problems were parts of this first test. "The cameras worked well," Griffin noted after the launch. "The foam did not."

It was also a test of NASA management, which showed what many observers considered a refreshing candor in discussing aspects of the mission that did not go as planned. Deputy shuttle program manager Wayne Hale e-mailed Discovery's crew, saying he was "mortified" by the external tank's foam loss and vowing, "We're going to fix it before we fly again."



DISCOVERY LEAPS off the launch pad July 26. STS-114 was the first space shuttle flight in 2½ years. After a 2-week mission that included a first-ever spacewalk to check heat-protective tiles under the orbiter, Discovery and its crew landed August 9 at California's Edwards Air Force Base.

"I think it was a good half-step forward," says Thomas Jones, a former shuttle astronaut. "They have realized that fooling themselves and fooling anybody else leads to getting people killed, like on Columbia. I was part of NASA until 2001, and we refused to look the foam problem in the eye." NASA isn't yet perfect, says Jones, but management's mindset has changed.

The Return to Flight Task Group, chaired by former astronauts Thomas Stafford and Richard Covey, issued its final report August 17. Covey noted

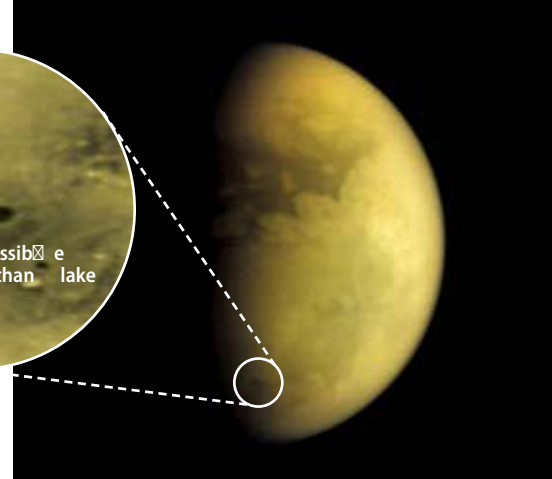
NASA's efforts to return Discovery to space showed proper assessments of risk. "We have to go fly to learn a lot of the things we learned on this flight."

At the end of August, Hurricane Katrina lashed the Gulf Coast at Mississippi and Louisiana as NASA prepared to ship external tanks from Florida to its Michoud Assembly Facility near New Orleans. The storm inundated New Orleans, but Michoud survived with damage estimated at \$500 million. The first external tank finally shipped in September, but mov-

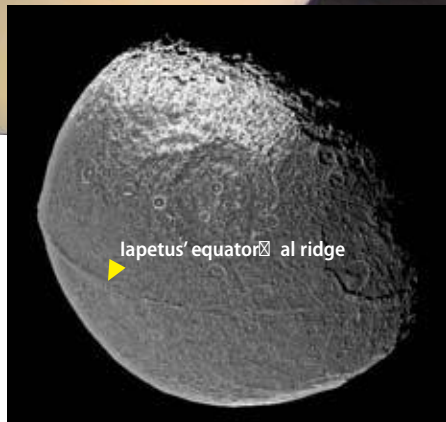
ing tanks to Michoud to resolve the thorny foam-shedding problem pushes the shuttle's next test flight well into 2006.

Only after a second successful flight will Griffin revisit the issue of a servicing mission to the Hubble Space Telescope. On August 28, Hubble engineers and scientists implemented a technique enabling observations with only two of the three gyroscopes normally required. As a result, the spacecraft now has two spare gyros — enough, astronomers hope, to keep Hubble working into 2008.

6 A year at Saturn ...



CASSINI VIEWS Titan (above) through filters that penetrate its thick haze. Inset: Cassini spotted this dark, footprint-shape feature during its June 6, 2005, flyby. Scientists say the feature's smooth outline, coupled with the continued presence of storm clouds near Titan's southern pole, make this the best candidate yet for an open body of liquid methane. ALL IMAGES THIS STORY: NASA/JPL/SSI



CASSINI CLOSED in on two-tone Iapetus December 31, 2004. The moon's rotation is locked to Saturn. This view is centered on the dark, heavily cratered hemisphere that leads Iapetus' orbit around Saturn. An 8-mile-high (13 kilometer) ridge runs along the satellite's equator.

On December 31, 2004, six months after the Cassini spacecraft entered orbit around Saturn, the probe flew by the 892-mile-wide (1,436 km), two-tone moon Iapetus. It's the solar system's highest-contrast body: One side is as bright as fresh snow, while the other is as black as tar. So far, Cassini images don't point to a unique explanation. The dark coating may come from within the moon, or it may be fine debris knocked off other moons by impacts that Iapetus picks up as it orbits.

The dark side holds a remarkable 12-mile-wide (20 km) ridge that runs at least

800 miles (1,300 km) almost exactly along the moon's equator. This feature rises 8 miles (13 km) above the surrounding terrain, but scientists don't know whether it's a mountain belt that has folded upward or a crack through which material inside the moon erupted onto the surface. Iapetus'

Spirit and its twin rover, Opportunity, were designed to operate for a minimum of 3 months on Mars, a "warranty date" both craft passed in April 2004. The rovers have returned some 35,000 images each, and they have inspected dozens of rocks and soil targets as they pursue geological evidence of water in the Martian past. "The mission has far exceeded our wildest dreams," says Mars Exploration Rover program scientist Curt Niebur.

Opportunity, which is exploring a region called Meridiani Planum, quickly found evidence its landing site had once been a beach at the edge of a salty, acidic sea. But Spirit, in Gusev Crater on the opposite side of Mars, saw only chemical traces of water until it drove 2 miles (3 km) cross-country and trekked into the Columbia Hill.

Once there, Spirit began finding a few more examples of rocks altered by water, but it took the ascent of Husband Hill to make Spirit

case for water at Gusev. "It wasn't until we got to Husband Hill that we were able to see rock outcrops that really opened our eyes to what Mars was like billions of years ago," Niebur explains. Evidence of rocks modified by groundwater is all around.

Husband Hill is the tallest of the Columbia Hills, a range lying east of Spirit's landing site. NASA has proposed naming the range in tribute to the space shuttle Columbia's last crew. Husband Hill, which rises 269 feet (82m) above the crater's surrounding plain, commemorates mission commander Rick Husband. From this summit, Spirit's cameras tantalized scientists with views of previously unseen layered outcrops on the hills' farside.

Relative to the rovers, scientists debated whether evidence for Martian water indicated long-lived earthlike conditions, like lakes and rainfall, or flash floods created by comet and asteroid impacts. Spirit and Opportunity have shown the truth lies in between.

ON TO THE WORLD For at least Gusev Crater, Mars rover Spirit captured this approximate true-color panorama from the summit of Husband Hill in late August. The rover took 14 months to ascend a height roughly equivalent to the Statue of Liberty.

NASA/JPL-CALTECH/CORNELL

spine may prove the key to understanding the moon's enigmatic coloration.

Saturn's largest moon, Titan, about 3,200 miles (5,150 km) across, is a misnomer on focal point. The first and most important discovery of Cass across the moon's southern pole. Dubbed "tiger stripes," these fissures are approximately 80 miles (130 km) long and 25 miles (40 km) apart.

"There appears to be a continual supply of fresh, crystalline ice at the tiger stripes, which could have been resurfaced very recently," says team member Bonnie Buratti at JPL. The stripes' freshest ice is probably less than 1,000 years old. "Enceladus is constantly evolving and getting a makeover."

What's more, Cassini's infrared spectrometer found the pole to be abnormally warm, some 27° F (5° C) above the equatorial temperature. Heat powers ice eruptions from the tiger stripes, scattering water vapor and dust into space and giving the moon an atmosphere.

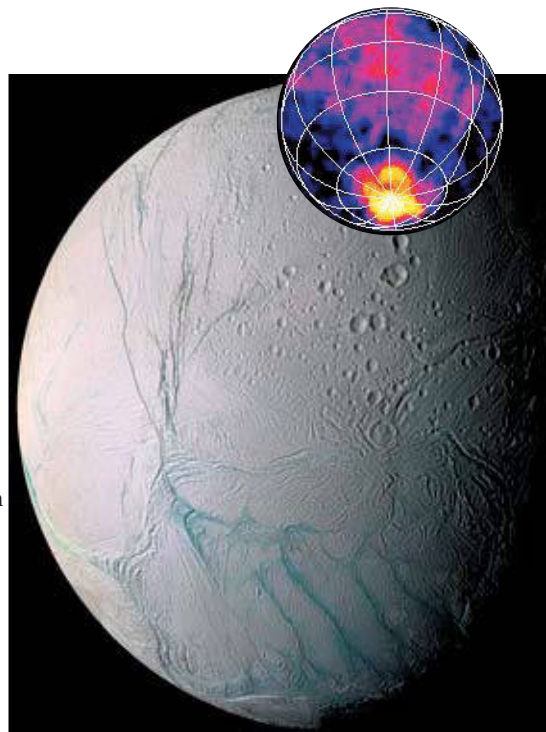
By far, the biggest surprises were at the moon Enceladus, where Cassini detected dust particles, a warm southern pole, and a thin atmosphere. On July 14, when Cassini swept within 100 miles (173 km) of Enceladus, the spacecraft's instruments discovered material emanating from the moon's surface. The Cosmic Dust Analyzer sensed a peak in the number of powder-size ice

particles, while closer in, the Ion and Neutral Mass Spectrometer recorded a spike in water vapor. High-resolution images show a series of roughly parallel cracks arcing across the moon's southern pole. Dubbed "tiger stripes," these fissures are approximately 80 miles (130 km) long and 25 miles (40 km) apart.

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"The fact that Enceladus is so alive and Mimas, the moon next door and roughly the same size, is so dead, is really testing our understanding of the internal workings of planetary satellites," says Carolyn Porco, Cassini team leader. Cassini next sweeps past Enceladus in March 2008.



ICE ENCELADUS cracks and heats itself. This Cassini false-color mosaic highlights the color difference between fresh ice outbreaks and the moon's "tiger stripes" and surrounding terrain. Inset: The stripes arc over Enceladus' south pole, which Cassini found was warmer (brightest colors) than the rest of the moon.

"One of the things that surprised me personally was the periodic nature of Mars' weather," Niebur says. "We are seeing earthlike climates, but they disappear for a period, and then they come back," he explains. "We're seeing a recurring earthlike climate on Mars deep in the past ... more than 2.5 billion years ago."

The rover team expected the missions of Spirit and Opportunity would come to an end after just a few months. Dust, they thought, would constantly accumulate on the rovers' power-generating solar panels, eventually becoming so thick the panels could no longer recharge the rovers' batteries.

But the Red Planet has been kind: Summer winds keep whisking the panels clean. Still, how long will the rovers last?

"That's the question we ask ourselves every day when we get out of bed," Niebur says. "Every day is a gift the excellent engineers at JPL have provided us."

... and two at Mars 5



OPPORTUNITY'S tracks scar the flatlands — a region dubbed Rub al Khali (Arabic for "the empty quarter").

NASA/JPL-CALTECH/CORNELL

4 Deep Impact



SPOKES OF LIGHT radiate from Comet 9P/Tempel 1's nucleus 67 seconds after it obliterated Deep Impact's probe. Most of the dust fell back to the comet after the impact.

July 4 fireworks came early for Comet 9P/Tempel 1. At 1:52 A.M. EDT, it barreled into a washing-machine-size, copper-fortified spacecraft at a combined speed of 27,000 mph (37,000 m/h). The collision blasted a crater out on the comet's nucleus and threw up a bright plume of dust studied by the Deep Impact mother-ship, which released the impactor. Observatories both in space and around the world looked on.

For JPL's Dign Yeomane, a member of the mission's science team, Deep Impact revealed a comet that defied expectations. "What turned out to be a surprise to me, anyway, is that there's no exposure of clean ice or frost on the surface." Thermal scans indicate there are no surface areas cold enough to be volatile substances like frozen water, carbon monoxide, and carbon dioxide. These ices must turn from solid to gas somewhere below the comet's surface.

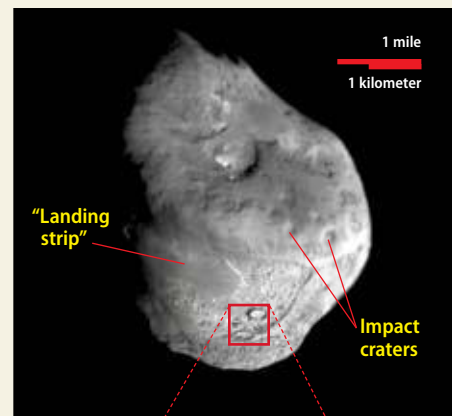
The impactor returned its final image of the comet about 10 seconds before it struck. Never before has a comet been seen in such detail — ridges, plateaus, plains, surface debris, and a hatbox-shaped impact crater are clearly visible.

"The craters were a surprise," Yeomane says. Neither Comet 19P/Borrelly, imaged by the Deep Space 1 probe in 2001, nor

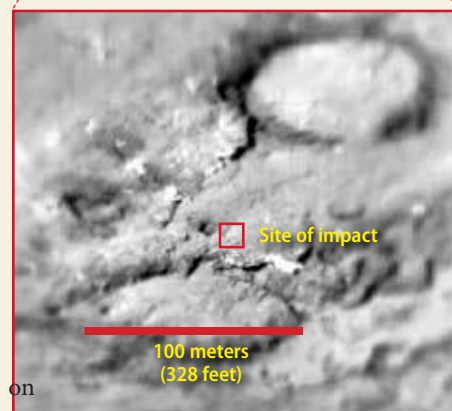
81P/Wild 2, explored by Stardust in 2004, shows obvious evidence of impact craters. On Tempel 1, the probable craters range in size from 130 to 1,300 feet (40 to 400m), but they have different characteristics on different parts of the nucleus. Near the crash site, where the inbound impactor acquired its highest-resolution images, the craters form circular ridges of slightly darker material. Elsewhere, they form smooth depressions. Analysis of crater distribution on the surface suggests a surface tens of millions of years old.

"And next door [to the craters], you've got this very smooth 'landing strip,' I call it, that's almost blemish free," Yeomane says. This indicates young terrain that recently has been resurfaced. The team suggests the cliffs at the "landing strip's" edge may be exceeding as material vaporizes from the surface, revealing older craters underneath.

The impactor struck with the energy equivalent of 4.5 tons of TNT, but scientists envisioned a range of possible outcomes based on the comet's composition. "We had a very fragile comet, and the crater formed rather slowly, over about 500 seconds. [As for] the ejecta curtain — not much of it left the comet at all. It went up and came back down over a period of several hours," Yeomane explains. "That suggests we were



CLOSING ON COMET TEMPEL 1, Deep Impact's probe imaged the nucleus in ever-greater detail. In these contrast-enhanced composites, detail increases toward the impact site because images at closer range replace those of the same locations observed from greater distance.



THE BEST-EVER VIEW of a comet's nucleus came to planetary scientists moments before the impactor struck.

dealing with a very weak cometary nucleus — something stronger than a snowdrift."

The response to the impact on Tempel 1 threw up a smokescreen of microscopic dust particles that prevented the flyby spacecraft from peering into — or even detecting — the resulting crater. The impactor couldn't have pulverized enough material to create the huge volume of micrometer-size particles in the plume, so the team believes Tempel 1's surface consists of dark dust grains in a powdery layer some tens of meters deep.

Minutes after the Deep Impact strike, the spacecraft swept within 310 miles (500 km) of the nucleus. Later, engineers executed a maneuver to return the flyby craft toward Earth. This opens the possibility of a gravity assist with Earth that would bring the probe to Comet 85P/Boethin in late 2008.

Bigger, better galaxies



TONY HALLAS

Lying just 2.5 million light-years away, the Andromeda Galaxy (M31) is the nearest giant spiral to our own. “We can actually observe things in Andromeda that we can’t in the Milky Way just because of our location within it,” says Rodrigo Ibata of France’s Strasbourg Observatory. “So, it’s the ideal test to understand a large disk galaxy.”

Ibata and colleagues have been studying the galaxy for years, but, in May, they announced something unexpected. The team had been using a sensitive spectrograph on the Keck Telescope in Hawaii to observe more than two dozen regions in and around M31. “We followed up on various little lumps that we found previously in another survey we’d been conducting,” Ibata explains. They thought the lumps were wreckage from small galaxies that plunged into Andromeda, forming part of its halo. “We were really expecting these things to be moving higgledy-piggledy all over the galaxy, and that was not the case at all.”

The astronomers measured the speeds of 2,800 red-giant stars beyond the edge of the galaxy’s visible disk — stars thought to be moving randomly in the galaxy’s halo. Yet, the team’s measurements show the stars are moving as if they reside in an extension of M31’s disk.

“It completely floored us,” says team member Scott Chapman of the California Institute of Technology. “I think we stared at the result for probably a month trying to figure out what we were doing to get it.” The astronomers traced this extended disk out to 220,000 light-years, effectively tripling M31’s size. If the entire disk were visible to the naked eye, M31 would appear more than 11 times larger than the Full Moon.

In August, a team led by Joss Bland-Hawthorn of the Anglo-Australian Observatory in Sydney, Australia, announced that NGC 300, a small spiral galaxy some 6.1 million light-years away in Sculptor, has an extended disk that doubles its size. “This is really a

A COLLISION with a gas-rich galaxy early in M31’s history may explain how it formed an extended disk of stars spanning 20,000 light-years. Discovery of the structure triples M31’s size.

huge surprise to us,” says team member Bruce Draine of Princeton University. The team found it stars up to 47,000 light-years from the galaxy’s center.

Chapman thinks different mechanisms are at work in M31 and the “puny” galaxy NGC 300, which has less than 20 percent of Andromeda’s mass. He believes M31 must have undergone a major collision with another gas-rich spiral early in its history. The gas is important because it could help modify stellar orbits on a shorter timescale than gravity alone, driving them into rotation with M31’s bright inner disk. In contrast, NGC 300 simply may have been unharmed by passing galaxies, enabling it quietly to grow a smooth, extended disk. In any case, the finds are “very hard to reconcile with computer simulations of forming galaxies,” he says.



ESO

NGC 300, 6.1 million light-years away, has less than 20 percent of M31’s mass, yet it, too, has an extended stellar disk. Astronomers think NGC 300’s extension must have formed differently from M31’s. They speculate this small galaxy grew in a quiet corner of the universe and gradually expanded.

2

On July 29, Caltech astronomer Michael Brown and his colleagues Chad Trujillo at the Geaini Observatorid on Mauna Kea, Hawaii, and David Rabinowitz at Yale University announced their discovery of a distant body larger than Pluto. It's temporarily designated 2003 UB₃₁₃, but playfully nicknamed "Xena" after the heroine of the TV show *Xena: Warrior Princess*. The object is the solar system's most distant body to be observed directly.

Since beginning a 5-year sky survey with Palomar Observatory's 48-inch Samuel Oschin Telescope in 2001, Brown's team has found several objects about three-quarters the size of Pluto's. These include Quaoar, Orcus, and Sedna. The astronomers first imaged Xena on October 21, 2003 — but the ice world moves so

slowly along its orbit that it eluded software designed to look for moving targets until the scientists reanalyzed their images January 5, 2004.

The newfound object now lies 97 AU from the Sun, 3 times Pluto's distance. (One AU, or astronomical unit, equals the average Earth-Sun distance.) Xena has reached the farthest part of its 557-year orbit. In 280 years, a little longer than Pluto takes to orbit once, 2003 UB₃₁₃ will reach its closest point to the Sun at a distance of 38 AU. Its orbit is also highly inclined (44°) to the plane of the solar system.

On January 25, using the Gemini North Telescope on Mauna Kea,

Hawaii, Trujillo studied Xena's near-infrared spectrum, which provides information about its surface properties. Preliminary results indicate a surface remarkably similar to Pluto's, covered in frozen methane.

If Xena reflects 70 percent of the sunlight reaching it, as does Pluto, then it's about 1,677 miles (2,700 km) across, or about 18-percent larger than Pluto. This would make it the largest object found in the solar system since Neptune's 1846 discovery.

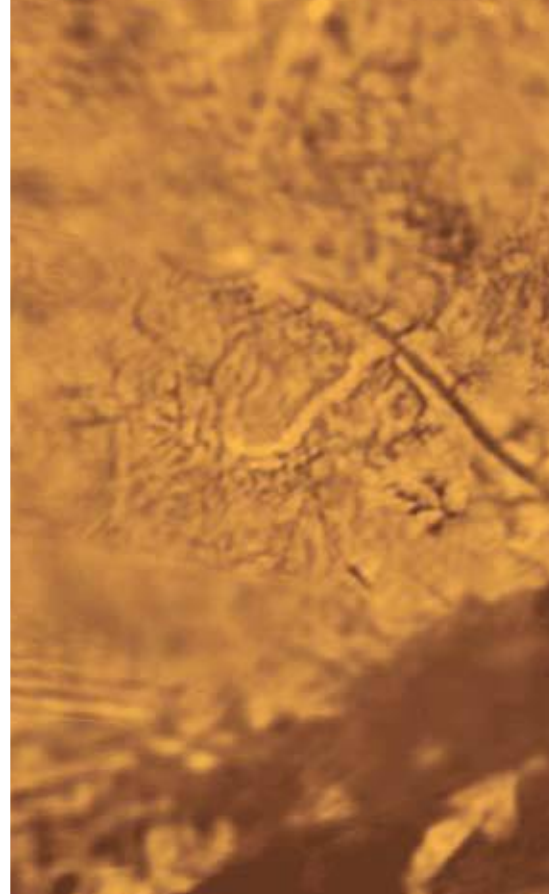
On September 30, Brown revealed Xena has a 155-mile-wide (250 km) moon, which he's nicknamed "Gabrielle," after the fictional Xena's sidekick. Now, three of the four largest objects in the Kuiper Belt have moons — a high ratio compared to the rest of the region.

Because Xena is larger than Pluto, Brown calls it the tenth planet. His team has submitted formal names for Xena and its moon to the International Astronomical Union (IAU), which approves all solar system names. But the IAU stated August 4 that 2003 UB₃₁₃ won't receive a formal name until a panel's efforts to define a planet's minimum size — ongoing since 1999 — reaches a conclusion. Brown calls this state of affairs "committee limbo."

Members of the IAU panel hint a consensus may come soon. The solution may involve placing Xena, Pluto, and similar objects into a class of their own — "trans-neptunian planets."



XENA AND ITS MOON, Gabrielle, orbit together in the Kuiper Belt, a swath of icy bodies at our planet's edge. FRANCIS REDDY



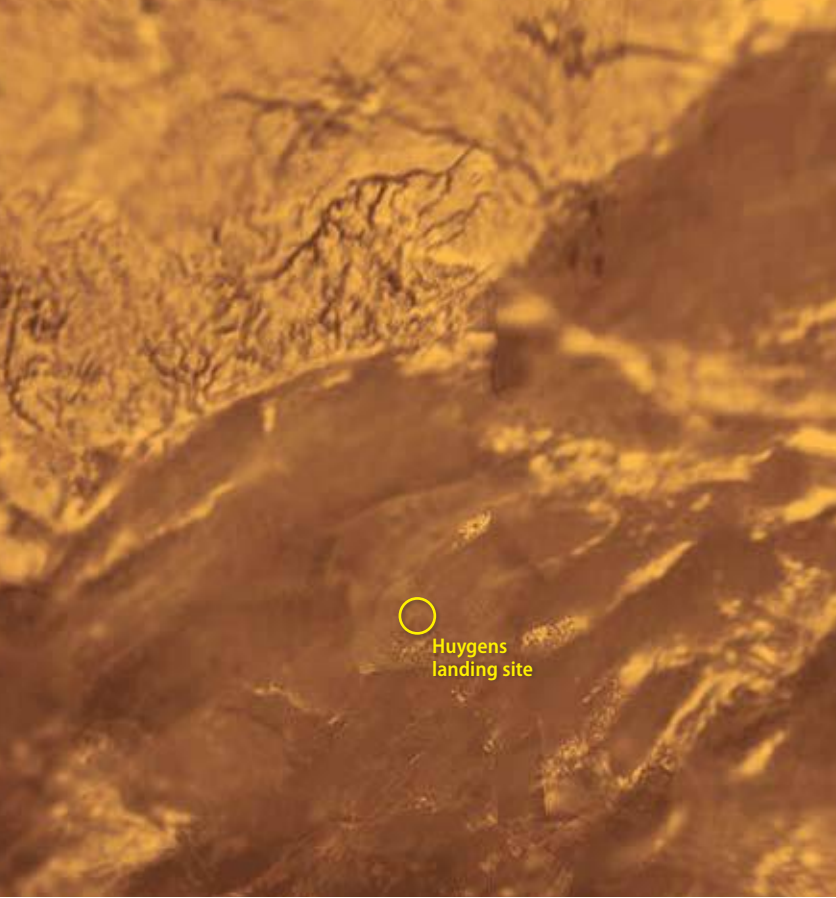
On January 14, after a 7-year journey from Earth and a 3-week cruise from its Cassini mother ship, ESA's Huygens probe plummeted into Titan's thick, hazy atmosphere to make the first direct study of a moon other than Earth's. As a hoped-for-but-unexpected bonus, the craft also made the most distant spacecraft landing ever attempted.

Huygens deployed a sequence of three parachutes to slow down and sample the atmosphere in exquisite detail. Transmitters beamed the probe's findings to Cassini, which relayed them to Earth.

During descent, a combination of turbulence and parachute stability problems sent the probe swinging on its chute with 3 or 4 times the force scientists had expected. And only in the final descent's first 10 minutes did Huygens spin in the intended direction.

One sensor was supposed to record each time it swept past the Sun so scientists could determine where cameras and other instruments were pointing. But the probe's wild swings and backward spin made the sensor lock up intermittently. "In the lower

Huygens lands on Titan



Huygens
landing site



A RIVER once ran through the Huygens landing site. The probe, facing south, returned this view from Titan's surface. Rounded, icy stones suggest Huygens landed in a dry streambed. The deep orange color is real.

ESA/NASA/JPL/UB UNIVERSITY OF ARIZONA

spectacular page in the data that we saw," Tomasko says. Titan has erosion, drainage channels, probably rainfall, and at least temporary lakes. It's a world with a water cycle like Earth's — but one where liquid methane, rather than water, plays the active role.

▲ THIS VIEW FROM HUYGENS combines descent images taken from 13.7 and 5.6 miles (22 and 9 km) above Titan. The color is approximately correct for a height of 9.9 miles (16 km). Bright areas to the north (top) and west are highlands. The dark, dendritic lines etched in them seem to be drainage channels. ESA/NASA/JPL/UNIVERSITY OF ARIZONA

30 km [18 miles], where we didn't see the Sun any longer, we basically took data at random angles," says Martin Tomasko, principal investigator of the Descent Imager/Spectral Radiometer (DISR) package on Huygens.

Worse, while Huygens transmitted its data on two separate channels, one of Cassini's two receivers never switched on. All data sent from one transmitter, including 350 images, were lost.

Assembling the images and other data was "like trying to put together a jigsaw puzzle where half the pieces are missing," Tomasko says. "And every time the probe tips and tilts, the shape of the pieces on the ground changes — and you don't have the picture on the front of the box." Soaking it all out took months longer than planned.

Tomasko compared taking the images to photographing "an asphalt parking lot at

dusk." Even Titan's bright highlands reflect only 12 percent of the available sunlight. If the Sun is visible at all from the surface, it appears as a disk 10 times smaller than what we see from Earth. It's similar in size and brightness to a car headlight seen from a block away. The moon's surface illumination — distinctly orange because haze particles strongly scatter blue light — equals what we experience on Earth about 10 minutes after sunset.

Despite these challenges, Huygens gave us the first detailed look at an alien landscape that, Tomasko says, also looks "eerily familiar." Drainage channels appear in bright, upland terrain and seem to feed into lower, dark terrain resembling a dry lakebed. "Titan, which had been so mysterious before, all of a sudden became a member of the terrestrial planets.... That was really a big turning point, and probably the most

After descending by parachute for 2.5 hours, Huygens finally jolted to a stop. The probe struck Titan's surface at a speed of 10 mph (16 km/h) and a deceleration of 15 Gs.

The temperature of the landing site was -291°F (-180°C). Huygens actually warmed Titan's surface so much that part of its icy soil boiled away, giving the probe's mass spectrometer a whiff of methane.

"Liquid methane was within a few centimeters of the surface," notes Tomasko. Despite the cold, the probe continued transmitting data for more than an hour after landing — far longer than scientists had hoped for.

Although Huygens is now a frozen part of the landscape it was sent to observe, scientists agree the probe gave them material to study for years to come. ■

ONLINE
EXTRA

Visit www.astronomy.com/toc for more on Huygens and Deep Impact.

{ GALACTIC ASTRONOMY }

A fugitive from the galaxy's edge

KAPTEYN'S STAR lies 13 light-years from the Sun, which, from that vantage, would be 3rd magnitude and visible to the naked eye in Hercules. Kapteyn's Star is far enough from us that other nearby stars would appear displaced, like Vega and Alpha Centauri. ASTRONOMY: ROEN KELLY

A century ago, a runaway star helped astronomers uncover the Milky Way's structure. /// BY KEN CROSWELL

Only 13 light-years away lies a unique star that holds clues to the formation of our galaxy: Kapteyn's Star. A refugee from the galactic halo, this star is one of the oldest in the Milky Way, and thus can tell astronomers about its beginnings.

Of the countless stars that spangle the Milky Way, those in the galactic halo are the oldest. The halo surrounds the spiral disk and formed when the galaxy did, but stars did not continue to form there as they did in the gas-rich disk. As a result, studying the halo helps astronomers decipher the Milky Way's early evolution.

But halo stars near the Sun are rare. Almost all nearby stars — such as Alpha Centauri, Sirius, and Vega — belong to the Milky Way's disk. Only one nearby star in 1,000 originated in the galactic halo. Kapteyn's Star is the closest of these stellar time capsules. In fact, it's the 24th-nearest star system to the Sun.

It's an inconspicuous red object that orbits the galaxy in the direction opposite that of the Sun and most of our stellar neighbors. This ancient star bears the name of Jacobus Kapteyn, the Dutch astronomer who codiscovered it, and whose greatest scientific love was the Milky Way itself. Ironically, Kapteyn's Star helped bring about the collapse of the galactic model Kapteyn championed.

The discovery of Kapteyn's Star

Kapteyn codiscovered the star in 1897 with Robert Innes, a Scottish astronomer working

at the Cape Observatory in South Africa. Astronomers at the Cape took photographic plates of the southern sky and sent them to Holland, where Kapteyn and his assistants measured stellar positions and brightnesses (see "Star counting" on page 53).

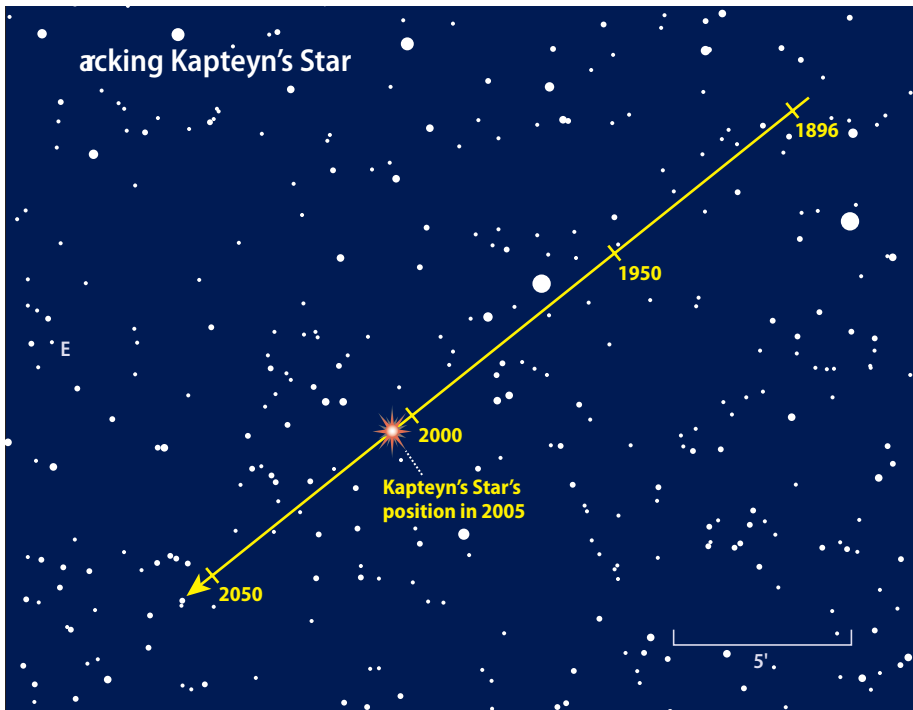
Kapteyn also worked with another Scottish astronomer, David Gill, at the Cape Observatory. The two astronomers began working together in 1885.

While examining Gill's plates in Holland, Kapteyn failed to find a 9th-magnitude star listed in an old star catalog. The missing star, "Cordoba Zone 5 hours 243," was supposed to be in the southern constellation Pictor. At

the Cape, Innes looked for the star through a telescope, but he couldn't find it either. He did, however, see a star matching its description just to the east. Gill wrote to Kapteyn and described Innes' find. "Can this be proper motion?" Gill asked. Sure enough, it was.

Proper motion is the year-after-year movement of stars across the sky; it results from both the star's motion around the galaxy and our own. Kapteyn's Star is shooting from northwest to southeast at 8.7" per year, faster than every other star then known. The previous record-holder, a yellow star in Ursa Major named Groombridge 1830, had reigned for more than half a century. This newfound star was the proper-motion champ until 1916, when American astronomer Edward Barnard discovered the only star to surpass it — a late named Barnard's Star.

The star Kapteyn and Innes discovered appears to have been renamed for Kapteyn in



KAPTEYN'S STAR SAILS through the sky at a rate of 8.7" a year. This chart shows where Kapteyn's Star has been, and where it's headed. ALL ILLUSTRATIONS BY AITRONOMY ROEN KELLY



A STAR'S COLOR indicates its surface temperature: the cooler the temperature, the redder the star.

the 1920s, after Kapteyn's death (it was previously called Cordoba Zone 5 hours 243). By then, Innes had made an even greater find: Proxima Centauri, the closest star to the Sun.

Faint though Kapteyn's Star was, its swift proper motion hinted it was also nearby. In 1898 and 1899, Kapteyn's student, Willem de Sitter, observed Kapteyn's Star from the Cape and measured its parallax.

Whereas proper motion gives a vague guide to distance, parallax gives a precise one: As Earth orbits the Sun, a star's position appears to shift because we view it from different perspectives during the year. The larger this shift, or parallax, the closer the star is to Earth.

Ken Croswell discovered a halo star located 90,000 light-years above the Milky Way's plane while studying at Harvard University.

The parallax de Sitter measured implied the star was 10.5 light-years away. Today's best parallax measurement, from the European Space Agency's Hipparcos satellite, places Kapteyn's Star at 12.8 light-years.

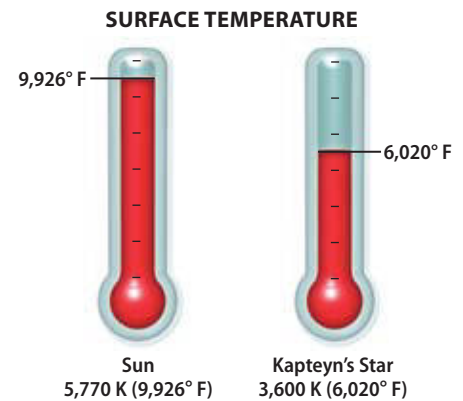
Wrong-way stars

The power of Kapteyn's Star lay in its large velocity. Two astronomers, Heber Curtis and George Paddock, working in Chile, struggled to measure the star's Doppler shift by capturing its spectrum on a photographic plate. This was difficult because the star is faint and red, and photographic plates then in use were most sensitive to blue light.

For 11 hours on 2 nights — December 1 and 2, 1908 — the star's light fell onto the photographic plate. Wrote Curtis, "Though very faint, some seven or eight [spectral]



A TYPICAL M-type dwarf star has a mass of about 30 percent of the Sun's.



SURFACE TEMPERATURES for main sequence stars range from about 2,000 K (3,000° F) to 50,000 K (90,000° F). The Sun and Kapteyn's Star are on the cooler end.

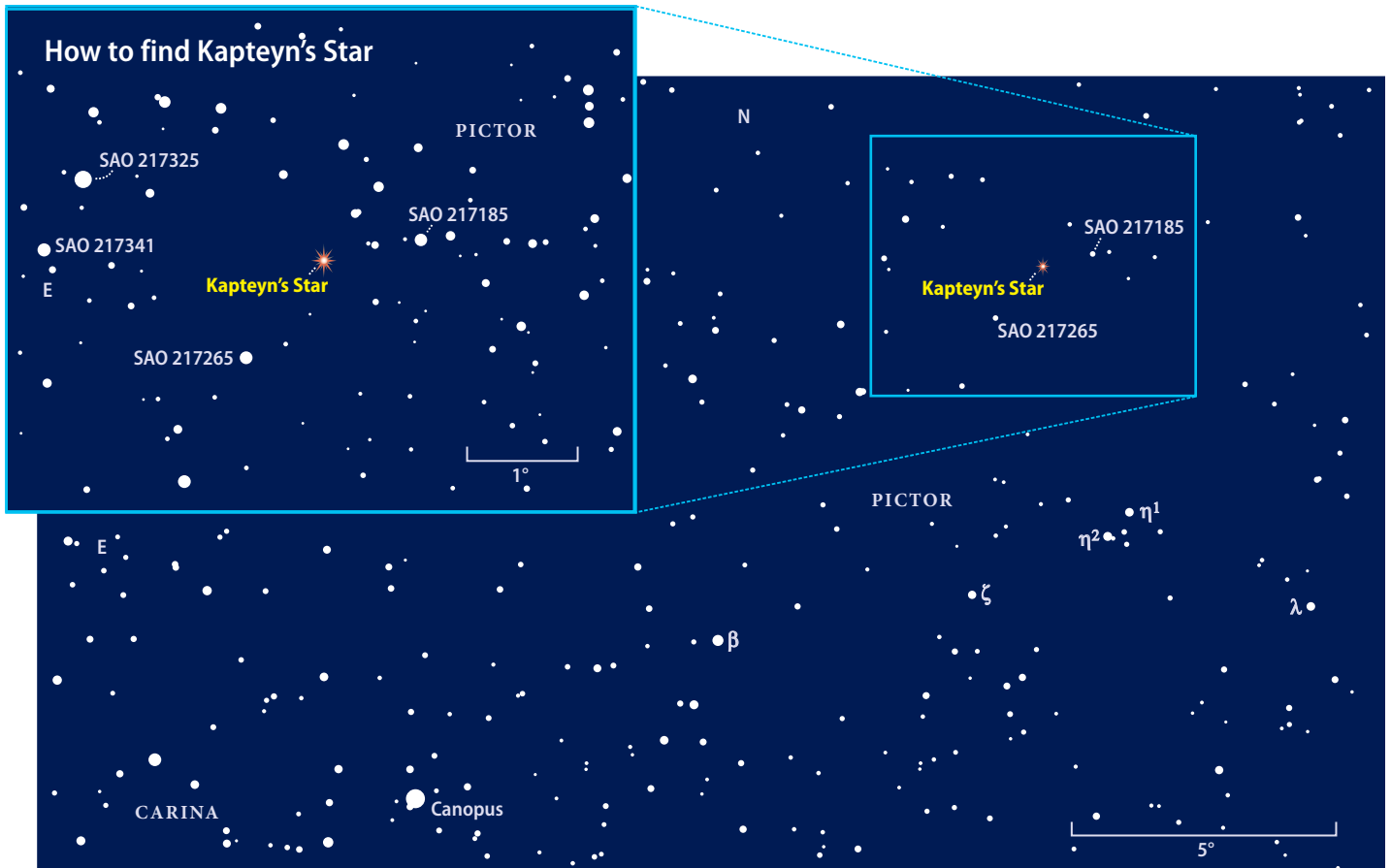
lines could be made out, and it was at once seen that the velocity was enormous."

After taking a second spectrum, which required 29 hours, the astronomers confirmed the star is speeding away from the Sun. The spectrum yielded a velocity close to the best modern one: 152 miles/second (245 kilometers/s). It was the fastest star ever seen. In the early 20th century, high-velocity stars, although rare, provided clues to a profound discovery.

In 1918, American astronomer Benjamin Boss, editor of *The Astronomical Journal*, analyzed the few high-velocity stars then known. He found that on one side of the sky, nearly all of them are racing away from us, while on the other side, nearly all are racing toward us.

What could this asymmetry mean? In 1923, Mount Wilson astronomer Gustaf Strömberg suggested the galaxy rotates rapidly. Ironically, Kapteyn's Star and its ilk revealed this rapid rotation because they did not partake in it.

Imagine riding on a fast merry-go-round. As the merry-go-round spins, you revolve around its center; so do other riders. Relative to you, though, their velocities are small, if anything at all. You are like the



IN A SPARSE REGION of the southern constellation Pictor lies Kapteyn's Star. Use this chart to find the 9th-magnitude speedy star. The object won't leave this field of view anytime soon: It will take 414 years to move 1° to the southeast.

Sun, and the other riders are like the normal low-velocity stars in the galactic disk. As you rotate, you see onlookers move past you quickly: Those behind you appear to race away from you, while those in front of you appear to race toward you. Of course, you're really doing the moving.

In like fashion, stars in the galactic disk revolve around the galaxy's center. That's why halo stars like Kapteyn's appear to move fast. In fact, as astronomers know today, the halo as a whole barely rotates at all.

Strömberg's work suggested, but did not prove, the galaxy rotates. Soon after Strömberg's suggestion, Swedish astronomer Bertil Lindblad, followed by Dutch astronomer Jan Oort, further analyzed stellar motions. Oort proved beyond doubt the Milky Way spins at high speed.

A red subdwarf

Halo stars held other secrets about the Milky Way's nature, not just the galaxy's

/// STAR COUNTING

Kapteyn's research mostly focused on the Milky Way's structure and stellar density — how the stars are arranged in the galaxy. Because he didn't have his own observatory, "Kapteyn presented the unique figure of an astronomer without a telescope," wrote American astronomer Frederick Seares. "More accurately, half the telescope of the world were his."

Kapteyn forged links with astronomers around the world, who supplied him with the data he needed. Writes Heber Curtis, another American astronomer, "His observatory has been his desk and a room fitted with instruments for measuring photographic plates; his subject-matter photographic plates and observations of other positions made by other astronomers; his tools the methods of mathematical analysis."

Kapteyn counted stars and estimated their distances by using their proper motions. This method was the key to the discovery of Kapteyn's Star.

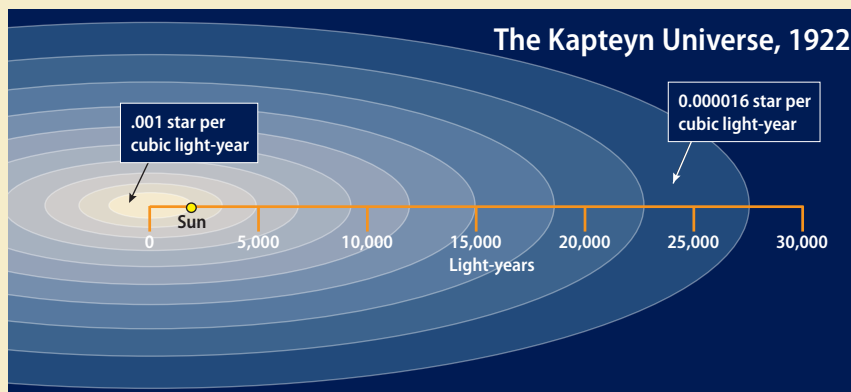
In 1885, Kapteyn began to collaborate with David Gill, a Scottish astronomer who directed the Cape Observatory in South Africa. Gill took photographic plates of the



AMERICAN INSTITUTE OF PHYSICS

JACOBUS KAPTEYN, the star's namesake, codiscovered it with Robert Innes.

southern sky and sent them to Kapteyn in Holland. Kapteyn and his assistants then examined the plates. The project culminated in a three-volume star catalog, *Cape Photographic Durchmusterung*, published in 1896, 1897, and 1900. It contains positions and magnitudes for 454,875 stars. — K. C.



ASTRONOMY: ROBIN KELLY AFTER J.C. KAPTEYN

GALACTIC STRUCTURE

Kapteyn's research focused on the big picture — the Milky Way. In 1906, he marked off 206 different areas. He asked astronomers around the world to measure the properties of stars in these regions. These observations would yield information about the Milky Way's stars along 206 different lines of sight. Observational astronomers still use Kapteyn's selected areas today.

From this data, Kapteyn thought he understood the Milky Way's structure. Our galaxy is small, he said, and we are near its center. The stars in the Milky Way revolve around the center at the modest speed of 12 miles per second (20 kilometers per second), he declared, which is slower than Earth's orbital speed around the Sun.

Kapteyn published his final paper on the so-called Kapteyn Universe in *The*

KAPTEYN'S GALACTIC MODEL used 10 ellipses to show the stellar density. His galaxy had a diameter of roughly 50,000 light-years. We now know the Milky Way's disk is more than twice that size.

Astrophysical Journal in 1922, the same year he died.

Unfortunately, despite his effort, his galactic model proved wrong. Ironically, stars similar to Kapteyn's Star were the first sign of trouble; they indicated the galaxy spins fast.

We now know the galaxy rotates at 140 miles/s (220 km/s) — 10 times faster than Kapteyn thought. Where did he go wrong? The space between the stars Kapteyn had counted contains gas and dust that dim distant starlight. Kapteyn thought he was at the center of the little he could see. — K. C.

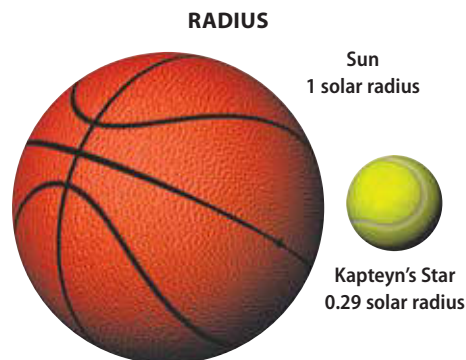
rotation. At first glance, Kapteyn's Star appears to be a red dwarf — a star much fainter, cooler, and smaller than the Sun. A red dwarf is a main sequence star, like the Sun, that generates energy by converting hydrogen into helium at its core, but it shines feebly because of its lesser mass. Kapteyn's Star emits only $\frac{1}{262}$ as much visible light as the Sun. Thus, Kapteyn's Star takes 9 months to generate as much visible light as the Sun does in a single day.

On closer inspection, however, Kapteyn's Star is actually a red subdwarf — a type of star that contributed to another discovery. In the 1920s, Dutch-American astronomer Willem Luyten noted Kapteyn's Star lies below the main sequence in an H-R diagram. In 1939, another Dutch-American astronomer, Gerard Kuiper, coined the term "subdwarf." Because main sequence stars are sometimes called dwarfs, he said stars still fainter should be called subdwarfs.

Meanwhile, astronomers were arguing over the origin of the elements on Earth — subdwarfs would play a key role in resolving this issue. In 1946, British astronomer Fred Hoyle began advocating that most of these elements had been created in stars. Hoyle's rivals believed, instead, these elements had been forged in the Big Bang.

In 1951, Joseph W. Chamberlain and Lawrence Aller measured the heavy-element abundances of two subdwarfs and proved Hoyle right. If the Big Bang had produced all of the elements, then stars should have the same element abundances. But if stars had created heavy elements (or metals) over time, older stars should have fewer metals, because they formed when fewer of these ele-

IRON ENTERED the galaxy at a slow rate, so old stars have much less iron than younger stars.



NOT UNTIL 2001 did scientists measure Kapteyn's Star's size; its radius is to the Sun's as a tennis ball is to a basketball.

ments existed. Chamberlain and Aller discovered two subdwarfs with lower iron and calcium abundances than the Sun.

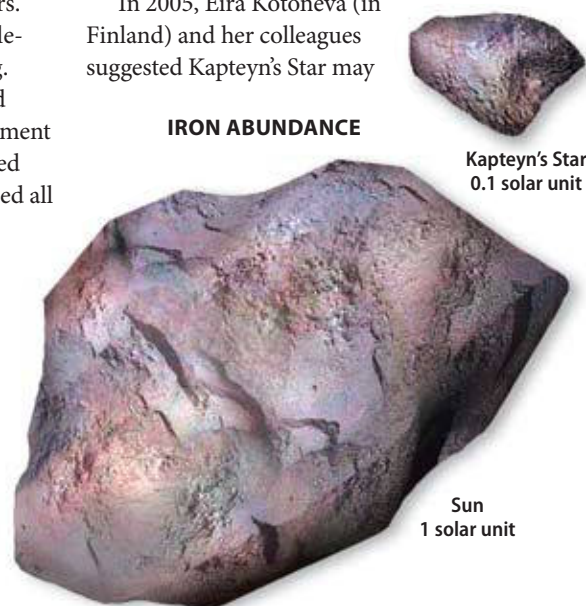
As a subdwarf, Kapteyn's Star is nearly as old as the galaxy itself. Although astronomers haven't measured its age, they have dated metal-poor globular star clusters, and found them to be among the galaxy's oldest objects. Like Kapteyn's Star, globulars inherited few metals because the ancient Milky Way had few to offer.

Kapteyn's Star has a peculiar orbit around the galaxy, which resulted from the star's ancient origin. According to a theory advanced by Olin Eggen, Donald Lynden-Bell, and Allan Sandage in 1962, the Milky Way formed when a giant gas cloud collapsed. The oldest stars, like Kapteyn's Star, therefore were born on elliptical orbits plunging toward the Milky Way's center.

Today, Kapteyn's Star is 27,000 light-years from the galaxy's center, which is about as far as it ever gets. Its closest approach brings it just 4,000 light-years from the center. In contrast, the Sun's distance varies only slightly, from 27,000 to 30,000 light-years.

In 2005, Eira Kotoneva (in Finland) and her colleagues suggested Kapteyn's Star may

IRON ABUNDANCE



have been born in Omega Centauri, the Milky Way's most luminous globular cluster, because both Kapteyn's Star and the cluster follow a similar path around the galaxy.

Furthermore, Kapteyn's Star orbits the Milky Way backward. If you could view the galaxy from high above the North Galactic Pole, you'd see nearly all stars, including the Sun, revolving around the galaxy clockwise. But Kapteyn's Star bucks the trend. It revolves counterclockwise — another sign of its ancient origin.

This orbit gives Kapteyn's Star the large proper motion that allowed Kapteyn and Innes to fish it from the celestial sea in 1897.

New research

Scientists continue to discover more about Kapteyn's Star. In 2011, Damien Ségransan

BRIGHTNESS



Sun
1 solar unit

Kapteyn's Star
0.0038 solar unit

BECAUSE OF ITS lesser radius and temperature, Kapteyn's Star has only 3.8 thousandths the Sun's luminosity.

at Geneva Observatory in Switzerland) and his team used the Very Large Telescope Interferometer in Chile to measure the star's diameter: 29 percent of the Sun's. Because a star's luminosity depends on both its diameter and temperature, this measurement allowed astronomers to determine the star's surface temperature of 3,600 kelvins. Furthermore, its luminosity implies a mass just 28 percent of the Sun's.

SPECTRAL TYPE



Sun
G2, main sequence



Kapteyn's Star
M1, red subdwarf

EACH ELEMENT SHOWS a unique signature in a star's spectrum, which allows astronomers to determine a star's composition. ASTRONOMY: ROEN KELLY; NOAO/AURA/NSF

In 2004, Vincent Woolf, now at the University of Nebraska in Omaha, and George Wallerstein of the University of Washington in Seattle determined the star's metal abundance. Red dwarfs and subdwarfs are faint, and they're so cool that molecules form in their atmospheres, complicating the analysis. Nevertheless, by using precise values for the star's temperature and surface gravity (obtained from its mass and radius), Woolf and Wallerstein analyzed a high-resolution spectrum. They determined Kapteyn's Star has 10 percent of the Sun's iron abundance.

They also measured Kapteyn's Star's abundance of titanium, a slightly lighter metal than iron. They found the titanium abundance is 15 percent of the solar value. Thus, although the star is metal-poor, its titanium-to-iron ratio is 50-percent greater than the Sun's.

Many elements, such as oxygen and titanium, arise in high-mass stars that explode as type II supernovae. Because high-mass stars die fast, they started exploding shortly after the galaxy was born, and even ancient stars like Kapteyn's inherited some of these elements. In contrast, iron entered the galaxy slowly. That's because i

TITANIUM was created in explosions of the earliest stars, so the element could enter the halo before stars like Kapteyn's were born.

large fraction of iron comes from the debris of white dwarfs. First, these stars take a longer time to form. Second, to explode, they must be in binary systems where they can accrete matter from another star. When they blow up as type Ia supernovae, they produce 0.6 solar mass of iron. As a result, a halo object like Kapteyn's Star has an above-solar titanium-to-iron ratio.

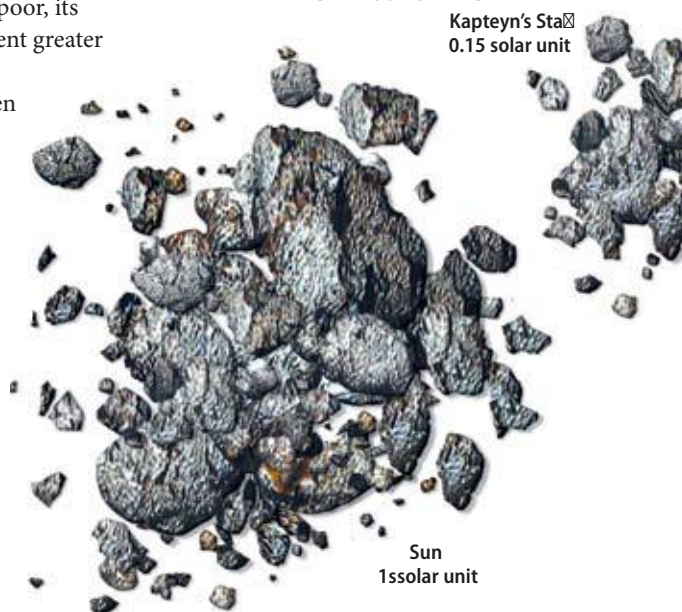
So even as Kapteyn's Star races away from Earth at more than half a million miles per hour, it still offers astronomers a glimpse into the galaxy's past — in a way that would have pleased its namesake.

ONLINE EXTRA

Learn more about Kapteyn and Innes at www.astronomy.com/toc.

TITANIUM AND NICKEL

Kapteyn's Star
0.15 solar unit

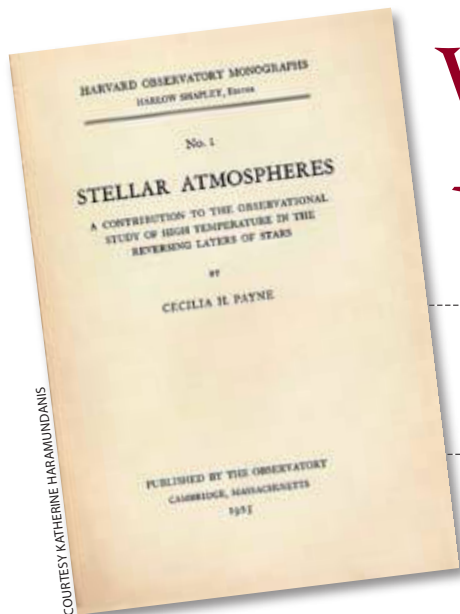


Sun
1 solar unit

THE LARGEST PROPER-MOTION STARS

Star	Constellation	Distance (light-years)	Spectral type	Apparent magnitude	Absolute magnitude	Discoverers	Year	Proper motion per year
Barnard's Star	Ophiuchus	5.98	M4	9.54	13.22	Edward Emerson Barnard	1916	10.51"
Kapteyn's Star	Pictor	12.80	M1	8.84	10.87	Jacob Kapteyn & Robert Innes	1897	8.66"
Groombridge 1830	Ursa Major	30.00	Gn	6.4	6.64	Friedrich Argelander	1841	7.06"

THE WOMAN who cracked the stellar code



COURTESY KATHERINE HARAMUNDANIS

Cecilia Payne-Gaposchkin laid the foundation of stellar astrophysics, fusing astronomy and the world of atoms. /// BY C. RENÉE JAMES

Doctoral candidates joke you could hide \$50 in the middle of your dissertation, and nobody on your committee would find it. Worse still, nobody outside your committee would even know your dissertation exists.

There are, however, exceptions. One has been lauded as “the most brilliant Ph.D. thesis ever written in astronomy.” While its title does not distinguish it from the typically dry thesis, *Stellar Atmospheres: A Contribution to the Observational Study of High Temperature in the Reversing Layers of Stars* is practically legendary. So is its author, Cecilia H. Payne (later Payne-Gaposchkin).

On May 11, 1925, just a day after her 25th birthday, Payne completed the oral defense of her thesis at Harvard Observatory. In it, she drew bold conclusions — claims that completely contradicted conventional wisdom.

The examination ended, and Payne spent hours agonizing in her office. There had been no word from her committee, a sure sign she had failed. On the contrary,

C. Renée James is a physics professor at Sam Houston State University in Huntsville, Texas.

her thesis advisor, Harlow Shapley, didn’t feel the need to report what he found obvious: Her work had been brilliant.

Payne’s thesis was a classic. It is a fantastic cliff-hanger, with a plot twist that ultimately revolutionized astronomy. Moreover, the story she tells is universal. It laid the foundation on which much of stellar astrophysics has been built for the past 80 years.

On the atomic level

As Cecilia Payne prepared her thesis, astronomy had begun morphing into astrophysics. Positions and motions of stars had been cataloged for centuries; but astronomers were now realizing a star’s spectrum could tell them about the star itself. They just weren’t sure how to interpret the language.

Most stars display an absorption spectrum. From as early as the 1860s, astronomers had known what produces such a spectrum. When light from a hot, dense object passes through a region of cooler, less-dense gas, the atoms in the gas act as a filter, picking off specific wavelengths of light. These are the same wavelengths those atoms emit if you zap them with enough energy. Atoms of a particular element interact only with specific wavelengths of light. Why atoms interact with light in such a selective manner was anyone’s guess.

In 1885, Johann Balmer noticed the wavelengths associated with hydrogen fol-

low a simple formula — now known as the Balmer Series — but he had no idea why.

Only in 1913, with Niels Bohr’s breakthrough of atomic structure did atomic spectra begin to make sense. Bohr demonstrated that electrons, discovered by Joseph John Thomson in 1897, exist only in well-defined energy levels — a series of steps.

To change levels, electrons must absorb or emit energy that corresponds exactly to the energy difference between the levels. Going up levels requires discrete amounts of outside energy — light of certain wavelengths. For example, when an electron is going down the steps, it releases discrete amounts of energy.

Once pushed to a higher energy level, electrons try to find their way back to the bottom — their ground state. On the way down, they have several options: They can take one step at a time, skip multiple steps, or hesitate in certain “metastable” states.

Until Payne, there had been little success at correlating laboratory atomic physics to stellar fingerprints. Astronomers had managed to sort and classify hundreds of

CECILIA PAYNE-GAPOSCHKIN’S WORK fused stellar astronomy with atomic physics. Her research impacted the study of stars’ compositions and life cycles, and enhanced astronomers’ fundamental understanding of the universe. ASTRONOMY:

KELLIE JAEGER; CECILIA PAYNE PHOTO AND STELLAR ATMOSPHERES EXCERPTS COURTESY KATHERINE HARAMUNDANIS



E=hc/λ

The uniformity of composition of stellar atmospheres is found to be an established fact. The quantitative composition of the atmosphere of a star is derived, in the present chapter, from estimates of the "marginal appearance" of certain spectral lines, and the inferred composition displays a striking parallel with the composition of the earth.

The observations on abundance refer merely to the stellar atmosphere, and it is not possible to arrive in this way at conclusions as to internal composition. But marked differences of internal composition from star to star might be expected to affect the atmospheres to a noticeable extent, and it is therefore somewhat unlikely that such differences do occur.

[illegible]



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IN JUST 2 YEARS, Cecilia Payne earned her graduate degree in astronomy. It was the first Ph.D. awarded from work done at the Harvard Observatory.

CECILIA PAYNE-GAPOSCHKIN

- **DATE OF BIRTH:** March 10, 1900
- **PLACE OF BIRTH:** Wendover, England
- **DATE OF DEATH:** December 7, 1979
- Earned her bachelor's degree in physics in 1923 from Newnham College, Cambridge University
- Moved to the United States to attend graduate school
- Awarded Ph.D. from Radcliffe in 1925 for her thesis titled *Stellar Atmospheres*
- The first person to earn a Ph.D. in astronomy from Harvard or Radcliffe, in effect creating an astronomy department associated with the observatory
- An observatory assistant at Harvard College Observatory after graduate work, because Harvard refused to promote women to professor
- Became an American citizen in 1931
- In 1934, awarded the Annie J. Cannon Award for a distinguished contribution to astronomy from the American Astronomical Society (AAS)
- Married Russian-born astronomer Sergei Gaposchkin in March 1934; they had three children
- In 1938, promoted to Harvard faculty
- In 1956, she became the first female tenured professor at Harvard, and the first woman department chair
- Named Professor Emerita after 1967
- Awarded the Henry Norris Russell Lectureship for a lifetime of excellence in astronomy, the highest award of the AAS, in 1976

O6.5

G2

M5

A STAR'S SPECTRUM depends on its temperature. Hot O-type stars have relatively clean spectra, while M-type stars, at the other end of the classification scheme, have cluttered spectra. Our Sun, a G2-type, is in between. ASTRONOMY: ROEN KELLY; NASA/ESA/ESA/Hubble

thousands of stellar spectra into the familiar sequence OBAFGKM, where O stars are hottest and M stars are coolest. Yet the messages encoded in the stellar rainbows had not been deciphered.

Look to the rainbow

Payne was determined to break the code. Why did different stellar spectral types exist? If you look at spectral types, you might believe that the M in M-type stars stands for “messy.” These spectra have more black absorption lines than color. Meanwhile, A-type stars display fairly clean spectra.

A naïve explanation is that M- and A-type stars contain different elements. You don't see many iron lines in an A-type star because it simply doesn't contain much iron. But this conclusion was philosophically distasteful. Astronomers were unanimous in their belief that the chemical content in the entire universe was uniform — a reflection of Earth's own makeup.

Earth is mostly iron and oxygen, and astronomers expected the same for stars. It was understood that Earth's low gravity and high temperature allow the lightest elements, hydrogen and helium, to escape our atmosphere. Astronomers thought the high temperatures of stars might disintegrate heavier atomic nuclei like iron into light elements. They expected stars' abundance pattern should be similar to Earth's — perhaps biased slightly toward lighter elements.

Deciphering stellar composition would take an incredibly dedicated approach combined with a lot of creativity. To apply laboratory data to the spectra features observed in stellar atmospheres, Payne needed to be familiar with the energy levels associated with each element. She would also have to know how atoms behave at certain temperatures and pressures.

Her approach was simple and straightforward. She addressed the problem from the beginning, assuming virtually nothing. The first 90 pages of her 200-page thesis were devoted to “The Physical Ground

work.” That foundation was shaky at times. The lab values she sought to apply were not always available, and when they were, they sometimes had enormous uncertainties.

Payne was aware of those limitations, and she recognized when her answers didn't make sense. Despite the occasional troubling result, her thesis glided along. By the third and final section, Payne had artfully reduced the vexing problem of stellar spectra to a non-problem.

The odd exception

Stellar spectra differ because of different temperatures and surface gravities. When all physical conditions are accounted for, most stars are strikingly uniform in their composition, at least on their surfaces. And the relative amounts of the elements in stars almost mimic the pattern on Earth.

But hydrogen and helium could be exceptions. The universe is mostly hydrogen and helium, which, according to Payne, “are manifestly very abundant in stellar atmospheres.” She reassured the skeptics: “The enormous abundance derived for these elements in the stellar atmosphere is almost certainly not real.”

Despite the fact that she buried the discussion of hydrogen in a few sentences of her two-page monograph, her results implied the presence of lots of the element.

Most thought stars simply couldn't be predominantly hydrogen. After all, stellar astronomy's leading expert, Henry Norris Russell, informed Payne that it was “clearly impossible that hydrogen should be a million times more abundant than the metals” — elements like iron and helium.

Still, the element's nature was there. The stars — at least on the surface — were mostly hydrogen. Unfortunately Miss Payne, not Doctor Payne, did the research. A young, female Ph.D. candidate simply could not win against common knowledge. Even though she did her research at Harvard College Observatory, Harvard would not grant her a degree; Radcliffe officially awarded it in 1925.

Piecing together stars' lives

Physics would improve, and ultimately, the astronomical community accepted Payne's conclusion about hydrogen, just as they had happily accepted her conclusion about the uniformity of stars.

Ironically, it was Russell himself who reported on the Sun's hydrogen content only 4 years later. There is no hint that Payne demanded more credit for the discovery. When it came to science, her philosophy was practical. "It doesn't really matter how you give the credit for a scientific discovery," she is quoted as saying, "for if one person doesn't discover it, someone else will."

Until you know stars' compositions, it is impossible to know what is going on inside. Only when astronomers established stars are mostly hydrogen, could hydrogen fusion be suggested as their power source. Stars could survive billions of years without the need for perpetual mixing, creating helium atoms from their abundant hydrogen stores.

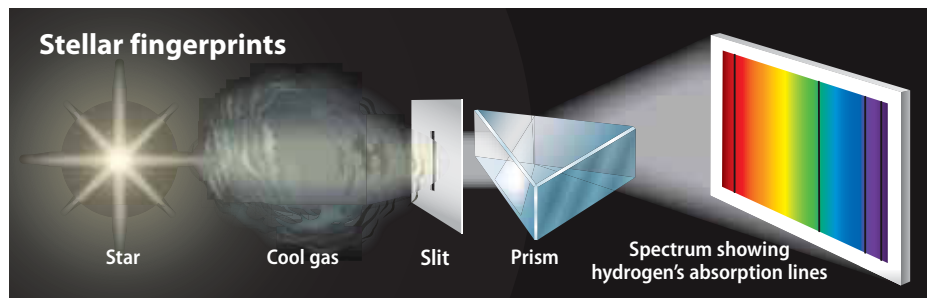
From knowing what the stars are made of and what powers them, astronomers could begin to understand stellar life cycles. Much of stellar astronomy originates in Payne's thesis.

On a more personal note

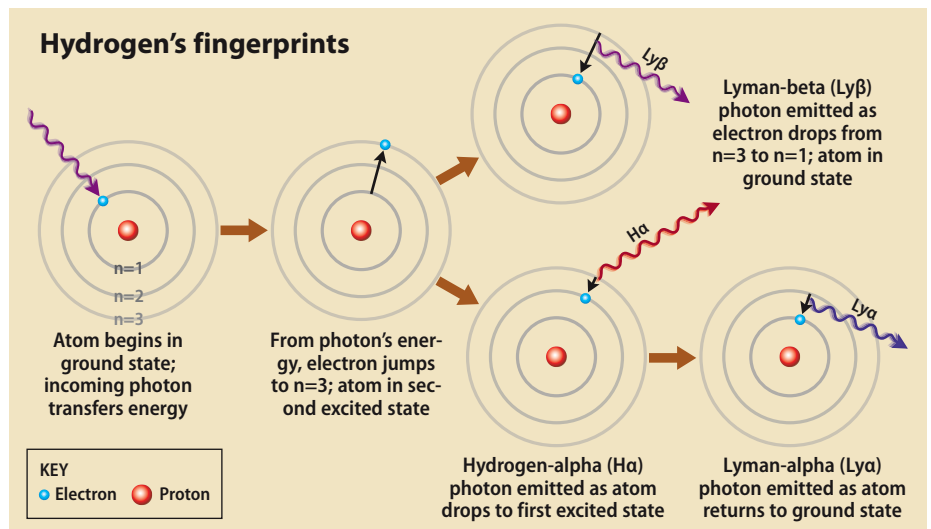
During her 54-year tenure as a Ph.D. astronomer, Payne-Gaposchkin (Cecilia Payne married Russian astronomer Sergei Gaposchkin in 1934 and sometimes hyphenated her name) made lasting contributions to several fields. Her publication record is dizzying, as is the list of honors and awards bestowed on her. But Payne's legacy goes beyond her astronomical work.

Throughout the decades, she worked with dozens of students, affecting the lives of the next generation of astronomy. Although she was a brilliant scientist, Payne would occasionally lash out when she felt her intellectual territory threatened. As a result, some students were afraid of her. One undergraduate assistant resigned shortly after witnessing Payne smash a collection of glass photographic plates to the ground in anger.

Most students, however, regarded her with a sort of reverent awe. "Many people thought she was something like the witch that lived in the gingerbread house, and that she was cooking us undergraduates up in her oven or something," recalls Kenneth Janes, now a professor of astronomy at Boston University. "But in her office, there was delightful chaos — the incessant noise of



AN ABSORPTION SPECTRUM is the result of radiation from a continuous source (such as a star) passing through a cool gas cloud. A star's outer layers are a cool gas compared to the hot, dense gas deep within the star. The cool gas absorbs certain wavelengths from the passing radiation. Those wavelengths are unique to different elements.



WHEN AN ATOM ABSORBS INCOMING ENERGY, an electron jumps to a higher energy level. As the electron drops energy levels, the atom falls toward its ground state — where it began — and emits energy in wavelengths that are unique to the specific element.

her calculator, the ineffectual efforts of Sergei Gaposchkin to flirt with the Radcliffe girls (to which [Payne] always called out 'Oh, Papa'), and one or two pairs of students calling out variable-star magnitudes."

For what would have been Payne-Gaposchkin's 100th birthday, the Harvard-Smithsonian Center for Astrophysics held a conference in her honor. Although organized rapidly, the conference drew nearly 200 participants to discuss fields where Payne had made her mark.

Topics covered everything from variable stars to galactic nucleosynthesis to the Magellanic Clouds. Some participants had known her personally, but most had not. Their only common ground was that Payne's work had somehow affected their careers.

Stars will continue to shine

Those who knew Payne-Gaposchkin say she never sought to impress anyone. She simply was in love with astronomy. She had

other passions, too: She recited Shakespeare by heart, wrote her own verse, and had a special affinity for Italy.

"There is no joy more intense than that of coming upon a fact that cannot be understood in terms of currently accepted ideas," she wrote in her autobiography. "Nature has always had a trick of surprising us, and she will continue to surprise us. But she has never let us down yet. We can go forward with confidence. 'Knowing that Nature never did betray / The heart that loved her,' " she quoted William Wordsworth.

There is little doubt that someone else would have reached the same conclusions about stellar makeup within a decade of Payne's thesis. But, perhaps, it took someone who didn't fit the mold of the traditional astronomer to see through accepted theories to what the universe is really telling us. ■

ONLINE EXTRA

Learn more about stellar spectroscopy, at www.astronomy.com/toc.

JANUARY 06

The ringed planet stands head and shoulders above its planetary brethren in January, despite Mars' valiant attempt to compete.

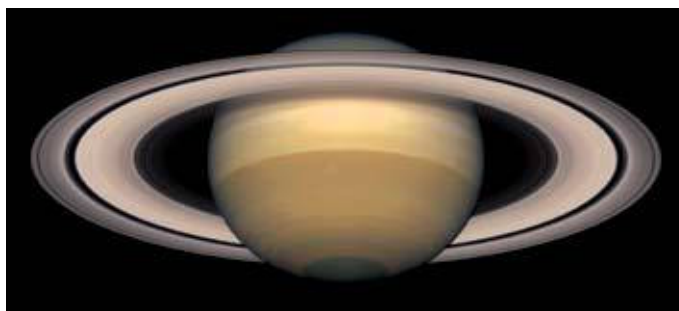
Saturn rules the night

The lord of the rings reaches the peak of its annual cycle this month. Saturn, ruler of the planets in mythology, dominates the sky from dusk to dawn. It lies opposite the Sun in our sky January 27, a configuration astronomers call an opposition. The planet then rises at sunset, climbs highest around midnight, and sets

near sunrise. It also shines brightest and appears largest through a telescope.

You might be tempted to observe Saturn as soon as the sky grows dark, but the view improves as the planet ascends during the evening. Turbulence in Earth's atmosphere causes blurry images, and the lower in the sky an object lies, the more atmosphere you have to peer through. For the same reason, avoid looking over rooftops or paved parking lots, where escaping heat can ruin the view.

A week or two before and after Saturn reaches opposition, its shadow disappears. It's the same phenomenon you see on a clear day if you stand directly between a friend and the Sun. Your friend's shadow vanishes because it lies behind him or her. But shift your head a bit to one side or the other, and the shadow pops into view. It's well worth following Saturn's changing shadow each clear night in the weeks around opposition. During the same time, you'll see the planet's brightest moons also shifting positions around the ringed wonder.



SATURN SHINES BRIGHTLY as it peaks this month, but the planet's radiance can't compare to its exquisite telescopic appearance.

NASA AND THE HUBBLE HERITAGE TEAM (AURA/STSC)

The steady orange beacon high in the south in the early evening is our closer planetary neighbor, Mars. It shines as brightly as Saturn, but only because its smaller disk lies much closer to Earth. Mars hangs around the evening sky until summer, so you might think you have plenty of time left to observe its subtle features. Alas, the orbits of Earth and Mars conspire to shrink the martian disk to a challenging size by February. It won't be as big and bright as it is now until October 2007.

From its perch in the evening twilight, Venus dives toward the Sun. For the past

several months, the planet seemed frozen in twilight's golden glow. But Venus takes only 2 weeks to disappear.

Mark your calendar for the first evening of the new year, when a crescent Moon joins Venus. Through a telescope, Venus also shows a delightful crescent shape, while steadily held binoculars reveal a tiny, delicate arc. Sharp-eyed observers just might see an elongated streak without optical aid.

The cusps of Venus' crescent elongate and join on the other side at inferior conjunction, when the planet lies between the Sun and Earth. You can view this phenomenon only

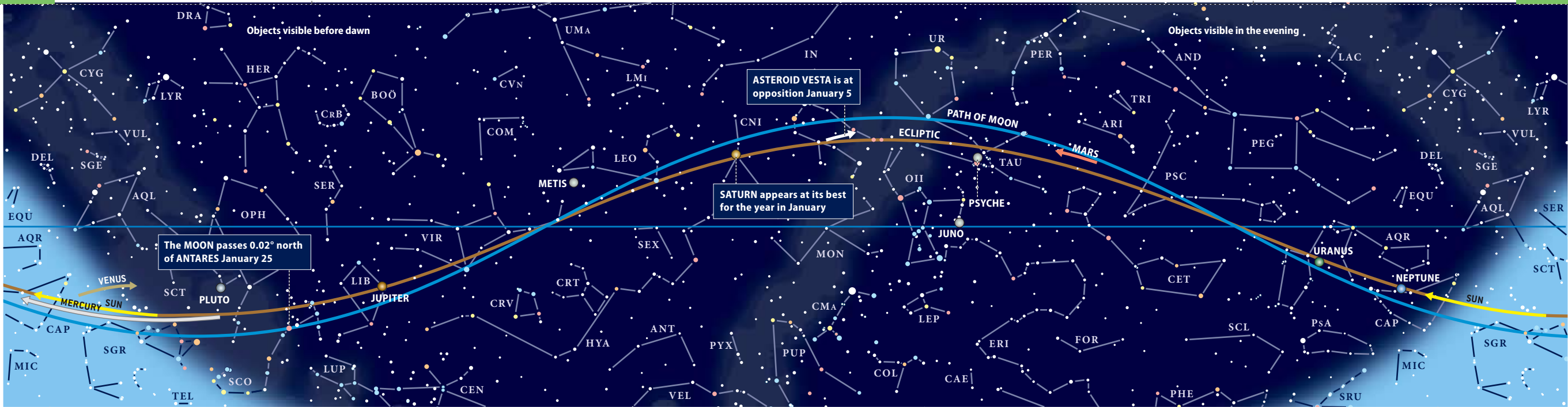
when Venus passes far enough from the Sun so you won't blind yourself looking. On January 13 at local noon, the planet stands 5.5° (about one binocular field) above the Sun and has only 0.5 percent of its disk illuminated. Make sure to hide the Sun behind the roof of a house or garage, put your scope in its shadow, and sweep straight up.

Observers in North America have ringside seats the evening of January 9 as the Moon passes in front of the bright Pleiades star cluster (M45). It's exciting to watch one star after another disappear instantly as the Moon's dark limb snuffs them out. Lucky observers from Texas to New England will have the chance to see a grazing occultation of Merope. This 4th-magnitude star pops in and out of view as peaks and valleys along the Moon's limb graze past. Another 4th-magnitude Pleiad, Atlas, does the same thing for viewers from Southern California to Michigan's upper peninsula. To find times for these events at your observing location, check out the International Occultation Timing Association's web site at www.lunar-occultations.com/iota.

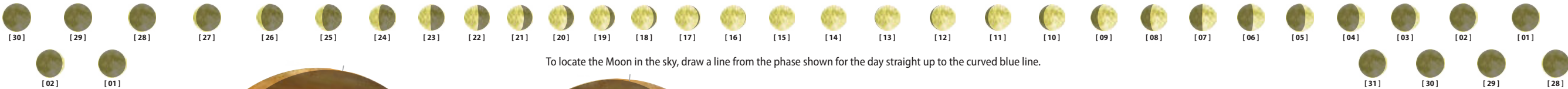
On January 4, Earth makes its closest approach to the Sun for the year. The perihelion of our slightly elliptical orbit brings us 1.5 million miles closer than average.

Planets this month

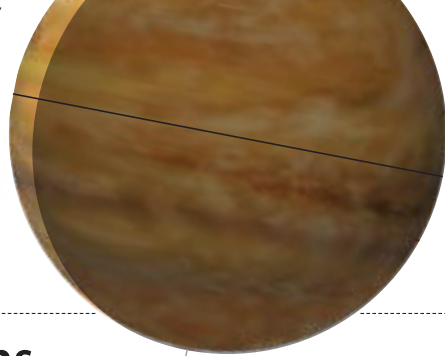
This map unods the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



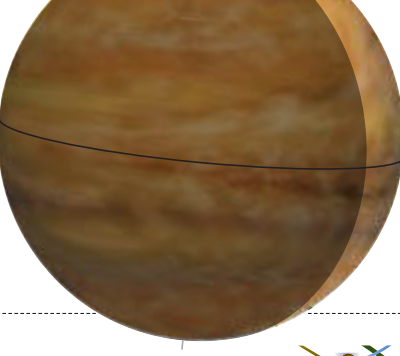
ALL ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY



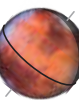
PLANETS	
Date	Jan. 1
Magnitude	-0.7
Angular size	5.1"
Illumination	92%
Distance (AU) from Earth	1.331
Distance (AU) from Sun	0.455
Right ascension (2000.0)	17h40.7m
Declination (2000.0)	-23°32'



VENUS	
Date	Jan. 1
Magnitude	-4.3
Angular size	58.0"
Illumination	6%
Distance (AU) from Earth	0.288
Distance (AU) from Sun	0.720
Right ascension (2000.0)	20h07.5m
Declination (2000.0)	-17°50'



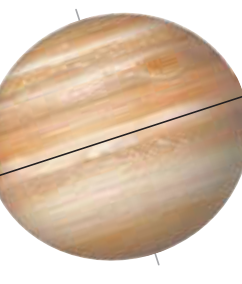
VENUS	
Date	Jan. 31
Magnitude	-4.4
Angular size	53.8"
Illumination	10%
Distance (AU) from Earth	0.310
Distance (AU) from Sun	0.719
Right ascension (2000.0)	19h06.6m
Declination (2000.0)	-15°23'



MARS	
Date	Jan. 1
Magnitude	-0.6
Angular size	12.1"
Illumination	92%
Distance (AU) from Earth	0.775
Distance (AU) from Sun	1.531
Right ascension (2000.0)	2h32.3m
Declination (2000.0)	16°35'



MARS	
Date	Jan. 31
Magnitude	0.2
Angular size	8.9"
Illumination	89%
Distance (AU) from Earth	1.052
Distance (AU) from Sun	1.569
Right ascension (2000.0)	3h14.5m
Declination (2000.0)	19°52'



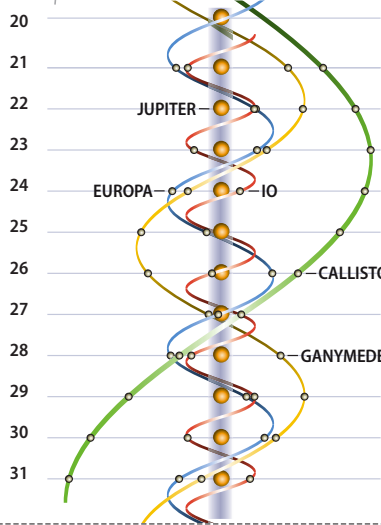
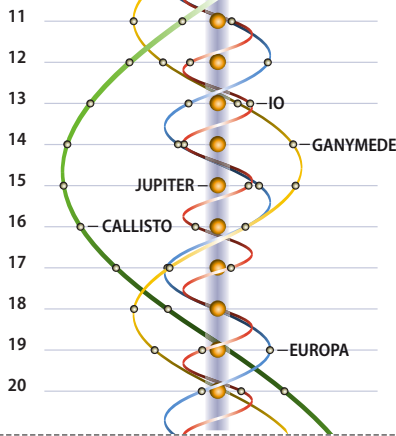
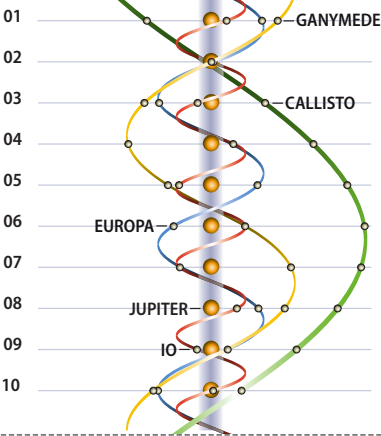
JUPITER	
Date	Jan. 15
Magnitude	-1.9
Angular size	34.5"
Illumination	99%
Distance (AU) from Earth	5.707
Distance (AU) from Sun	5.438
Right ascension (2000.0)	14h52.7m
Declination (2000.0)	-15°21'



SATURN	URANUS	NEPTUNE	PLUTO
Jan. 15	Jan. 15	Jan. 15	Jan. 15
-0.2	5.9	8.0	14.0
20.4"	3.4"	2.2"	0.1"
100%	100%	100%	100%
8.153	20.776	30.969	31.905
9.109	20.075	30.058	31.059
8h45.7m	22h40.6m	21h15.5m	17h40.6m
18°41'	-9°11'	-16°05'	-15°54'

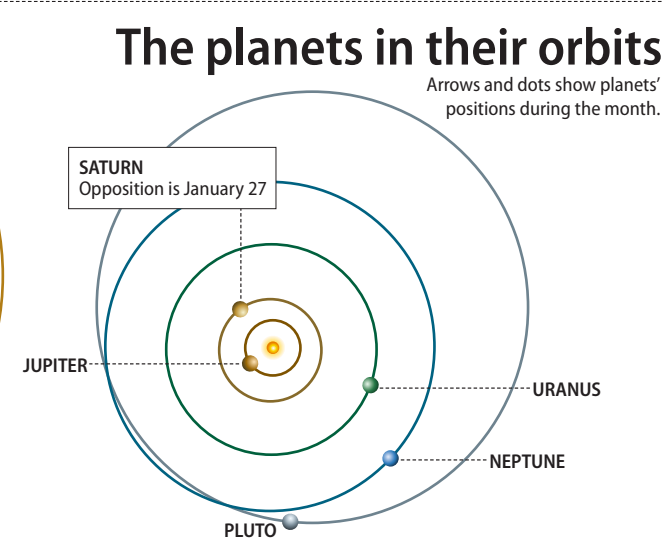
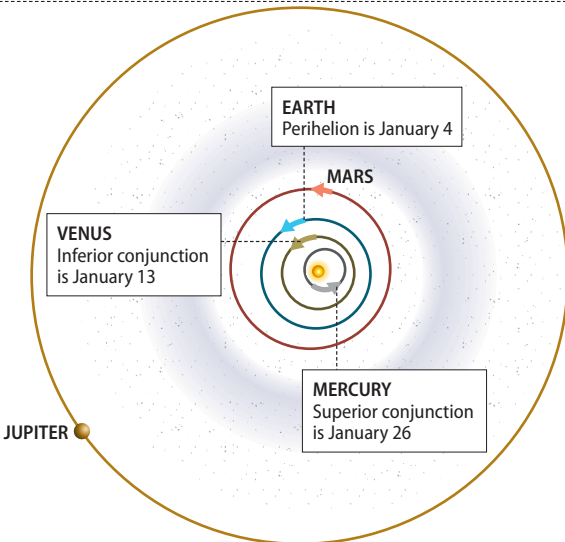
Jupiter's moons

Dots display positions of Galilean satellites at 6 A.M. EST on date shown. South is at top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during the month.



E



	Sirius		Open cluster
	0.0		Globular cluster
	1.0		Diffuse nebula
	2.0		Planetary nebula
	3.0		Galaxy
	4.0		
	5.0		

find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

W

ILLUSTRATIONS BY ASTRONOMY: ROEN KEI IY

- ONLINE EXTRA** For definitions of terms, visit www.astronomy.com/glossary.

For definitions of terms, visit www.astronomy.com/glossary.

THE DEEP SKY

The celestial giraffe stretches across winter's northern sky, bringing observers few bright stars but plenty of attractive asterisms, associations, and clusters.

A pair of binaries

In an April Fool's newsletter of the Edmonton, Alberta, astronomy club, a member once joked that Camelopardalis was Latin for "large vacant area of sky." With the naked eye from a suburban backyard, most would find this an apt description of the constellation. But don't let this mislead you: Several treasures await in the apparent void.

Camelopardalis' two brightest stars lie about halfway between Polaris and the bright star Capella in the northeast. The one closer to Capella is the double star Beta (β) Camelopardalis. Its 7.4-magnitude companion is a challenge for binoculars, but any scope will show it easily. The wide pair 11 and 12 Cam lies 1.5° closer to Capella. Approximately 3', or 10 percent the Moon's apparent width, separate these two, so

they appear as distinct points of light through binoculars.

It surprises many beginners to learn binoculars open up a realm not accessible with a telescope. Their wider field of view reveals larger structures that remain all but invisible through a scope. To view the binocular treats in Camelopardalis, head to a dark location during the second half of the month, when the Moon is out of the sky.

Kemble's Cascade

To find our first stellar group, aim at a point halfway between Polaris and Capella, then shift about one binocular field (6°) toward Alpha (α) Pers4i. You should see a series of 7th- to 9th-magnitude stars spanning half the field, with a couple of pairs thrown in. This pretty arrangement is called Kemble's Cascade. Astronomers



PRESTON COTTRELL

DOZENS OF FAINT STARS and several bright ones populate NGC 1502, an open cluster with an obvious central condensation that lies at the southeastern end of Kemble's Cascade.

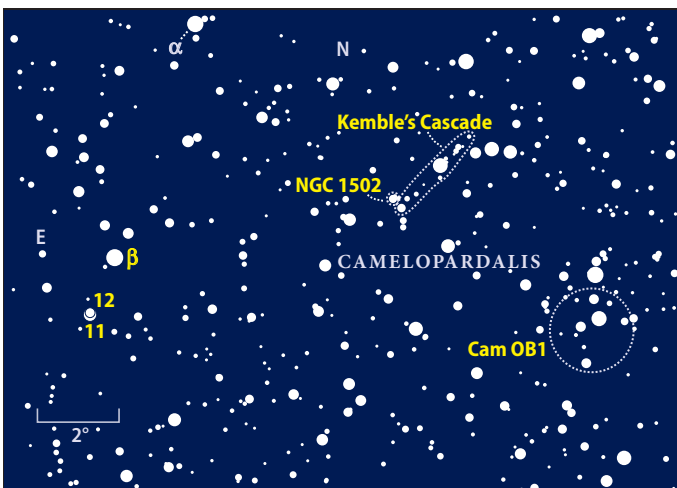
designate such groups asterisms, when the stars catch the eye but whose members are physically unrelated.

In contrast, stars born together have similar ages and move with one another through space. If gravity only loosely binds the stars, astronomers call these groups associations. A nice example, the Camelopardalis OB1 association, lies one binocular field southwest of Kemble's Cascade. The O and B stand for the spectral letters of hot stars. A more distinct OB association, the Alpha Persei moving group, lies nearby.

Martin Ratcliffe is the former president of the International Planetary Society. **Alister Ling** is a meteorologist for Environment Canada.

Gravity's hold on associations is so weak they disperse after a revolution or two around the Milky Way's center. Groups with greater numbers of stars exert more gravity and can stay together much longer. Such open clusters abound in and near the galaxy's spiral arms. A classic example in Camelopardalis is NGC 1502, which lies at the southern end of Kemble's Cascade. In fact, Saskatchewan amateur Father Lucian Kemble was looking for NGC 1502 when he stumbled across the star chain some 30 years ago.

Through a telescope, NGC 1502 displays a pair of yellow suns set against a triangular splash of stars. At magnifications of 150x or more, you should spot some tight pairs.



STARS IN MYRIAD FORMS — singles, doubles, asterisms, associations, and open clusters — highlight the inconspicuous northern constellation Camelopardalis. ASTRONOMY: ROEN KELLY

THE PLANETS

Planet observers will embrace Mars in the evening sky and Jupiter before dawn, but they will save their greatest praise for Saturn's wonderful all-night vigil.

As the winter Sun sets in the southwest, **Mars** glimmers high in the southeast. You'll find it as a bright, ruddy object west of the Pleiades, or Seven Sisters, star cluster (M45). During January, Mars moves eastward relative to the background stars through the constellation Aries, ending the month just 8° shy of the Pleiades. On January 8, a waxing gibbous Moon stands beside Mars, drawing attention to the Red Planet.

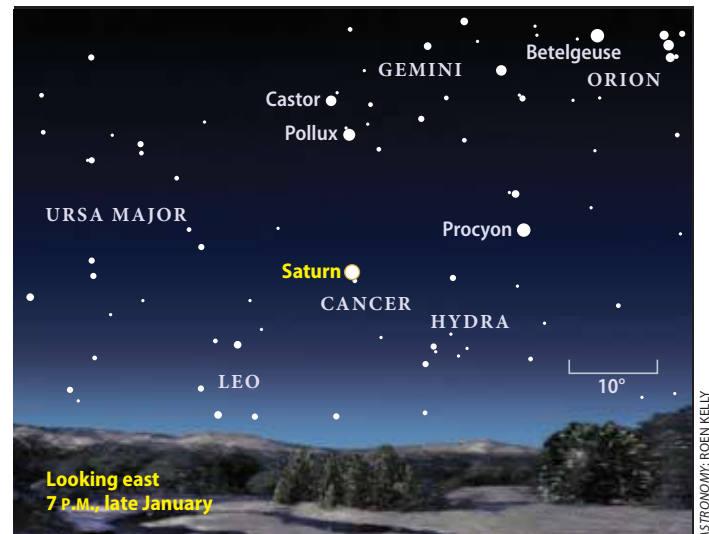
Although Mars will remain in the evening sky for many months, its diminishing size will reduce its appeal as a telescopic target after this month. On January 1, the planet has a respectable 12" apparent diameter and shines at magnitude -0.6. Telescopes with apertures of 6 inches or more will capture plenty of surface features. For example, in the early evening (8 P.M. EST) of January 1, Mars'

gibbous disk displays Meridiani Sinus prominently. At the same time January 10, Syrtis Major — the planet's most conspicuous dark feature — lies at the center of the martian disk.

Mars' diameter falls below 10" by January 19. An early evening view shows Mare Sirenum dominating the southern hemisphere. Later in the evening, Mare Cimmerium and Mare Tyrrhenum appear prominently.

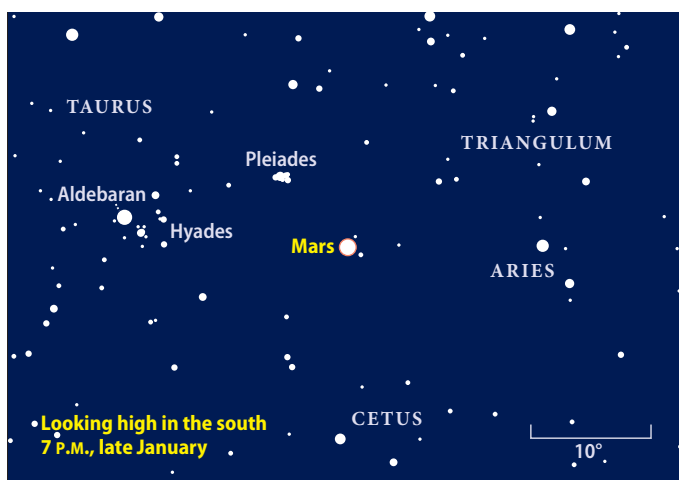
By the end of January, Mars has dimmed noticeably to magnitude 0.2 and shows a more distinct gibbous phase. The "eye" of Mars, Solis Lacus, then appears front and center on the planet's 9"-diameter disk in the early evening. Observers lucky enough to have steady atmospheric conditions and a 10-inch or larger scope will get good views.

As soon as the January sky darkens, **Saturn** pokes above



ASTRONOMY: ROEN KELLY

SATURN RISES AT SUNSET and lies high in the south at midnight, near the Beehive star cluster (M44) in Cancer.



MARS REMAINS BRIGHT this month, but it has faded from autumn's peak. The Red Planet nears the Pleiades star cluster as January draws to a close.

ASTRONOMY: ROEN KELLY

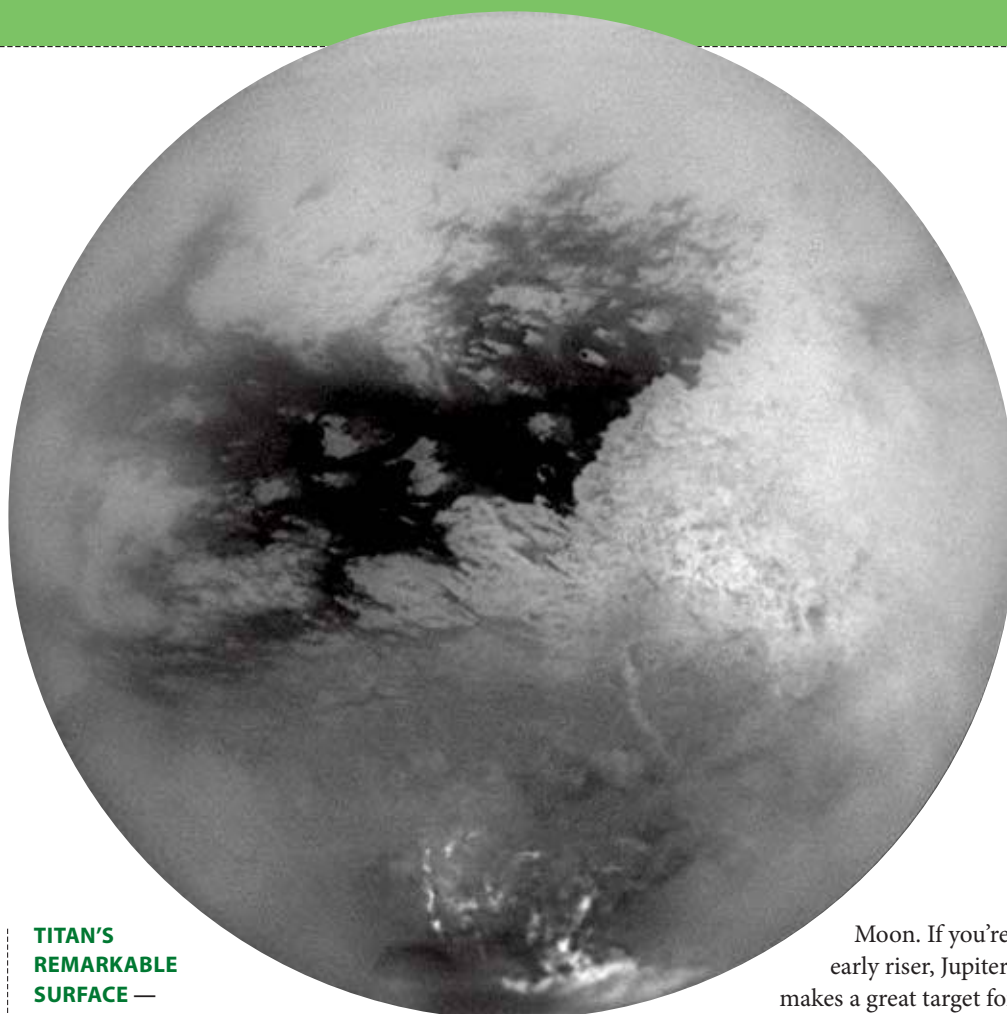
the eastern horizon. Resist the temptation to look too early, however. The planet's low altitude severely affects the view's clarity. By 10 P.M. local time January 1, Saturn has climbed 30° in the east. Few experiences match frozen fingers trying to focus a telescope, only to be rewarded with a spectacular, crisp view of Saturn's rings. By the end of January, Saturn reaches this respectable altitude 2 hours earlier, and by 10 P.M., your frozen fingers will be ready for a hot cup of cocoa.

Saturn reaches opposition January 27, the peak of its current apparition. It then lies closest to Earth, 755 million miles away. You can spot it easily among the faint stars of Cancer the Crab. Throughout the month, Saturn lies in the same binocular field as the prominent Beehive star cluster

(M44). This spectacular chance alignment gives observers an added treat.

Saturn shines at magnitude -0.2 during most of January, and the planet's disk swells to 20" at opposition. Its rings, however, more than double this apparent size, spanning 46". We now find ourselves within 3 years of an edge-on view of the rings. A few years ago, the entire outer ring could be traced south of the planet's disk thanks to the greater tilt. No, the disk blocks the ring. Still, a small scope delivers great views of the rings and of the Cassini Division, a dark gap that separates the outer A ring from the brighter B ring.

Any telescope shows Saturn's brightest moon, 8th-magnitude Titan. It lies due north of the planet January 1 and 17 and due south January 9 and 25.



TITAN'S REMARKABLE SURFACE —

revealed within the past year by the Cassini and Huygens probes — apparently has been scoured by methane rain and rivers. NASA/JPL/SSI

On the 25th, take care not to confuse Titan with a brighter star that lies in the same field of view. Gazing at Titan this year may feel a little different. It was just 12 months ago that Europe's Huygens probe landed on the moon's surface, giving professional and amateur astronomers alike their first close-up look at the surface of this haze-shrouded world.

Saturn's other moons prove more challenging to observe. A 6-inch scope will bring the 10th-magnitude trio of Tethys, Dione, and Rhéa into view. Tethys zips around the planet in

less than 2 days, Dione takes nearly 3 days, and Rhea more than 4 days.

Iapetus is just as easy to see when it lies far west of Saturn and glows at magnitude 10.1. But it appears 5 times fainter at greatest eastern elongation because its coal-black hemisphere then faces us directly. Iapetus spends January moving from west to east of the planet and fading steadily. On January 10, the two-faced moon passes a little south of the planet's disk.

Jupiter rises about 3 A.M. in early January and lies 30° high in the southeast as dawn breaks. It dazzles us in the normally faint region of sky occupied by Libra the Scales.

On January 23, Jupiter lies 5° above the waning crescent

Moon. If you're an early riser, Jupiter makes a great target for your telescope. You'll have no problem spying its four bright moons and two dark equatorial belts — the first atmospheric features most people see on another planet. Experienced observers know that spending a few extra minutes at the eyepiece will bring more subtle atmospheric features into view.

Mercury remains visible in the morning twilight as January opens, but it's sinking fast. It lies 15° west of the Sun January 1 and rises an hour before our star. But the shallow angle of the ecliptic to the southeastern horizon before dawn this time of year hinders the view. You'll need a flat horizon and good atmospheric transparency to spot it.

As Mercury disappears behind the Sun this month, **Venus** passes in front of our star. Venus' rapid motion means it appears low in evening twilight during January's first week and low in morning twilight during the month's final 10 days. The planet's brilliance helps it shine through the twilight glow.

The best views for Northern Hemisphere observers come toward the end of January. On the 27th, a slim crescent Moon stands 15° to Venus' lower right. A telescope shows Venus has the same 7-percent illumination as the Moon. The planet then measures a hefty 57" across.

Finally, **Ea** takes its closest approach to the Sun for the year this month. On January 4, our home planet reaches perihelion, when it lies 91.4 million miles from the Sun.



JUPITER'S GALILEAN MOONS line up nicely on either side of the planet's equator the morning of January 28.

ASTRONOMY: ROEN KELLY

METEORS AND MOONS

As far as prolific meteor showers go, it's hard to beat the Quadrantids. And this year, they peak with the Moon out of the sky. When the Moon returns, set your sights on the crater Arzachel.

Winter's stellar shower

One of the year's best meteor showers — but ironically one of the least observed — makes its appearance in early January. The Quadrantid meteor shower remains active from January 1 to 5, peaking on the 3rd. Two factors conspire against the Quadrantids: They come at the coldest and cloudiest time of year, and the number of meteoroids drops off dramatically from a sharp peak, so observing more than a day away yields few sightings.

Viewing conditions should be good this year, with the waxing crescent Moon setting before 9 P.M. local time. Earth crosses the thickest part of the shower's stream around noon EST on the 3rd, so observers should try viewing early that morning (the night of January 2/3). As always, find a spot far

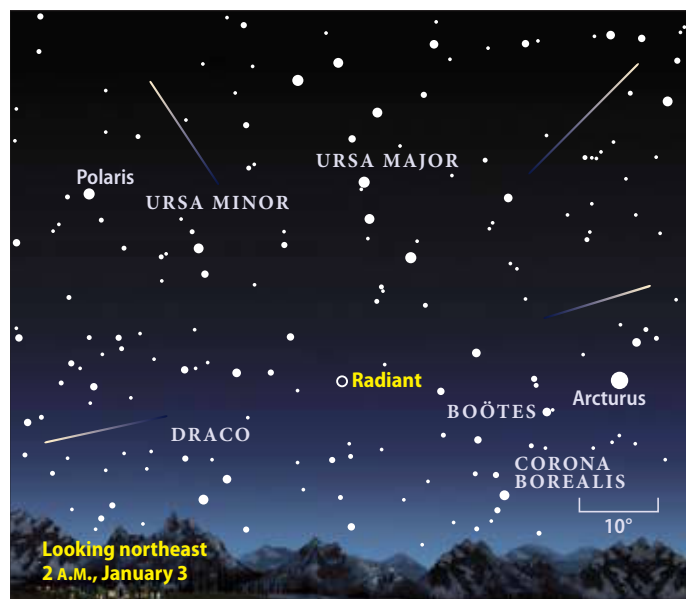
from artificial lights if you want the best view.

The shower's radiant lies in Boötes the Herdsman. This region used to belong to the now-defunct constellation Quadrans Muralis, the shower's eponym. The radiant passes nearly overhead as dawn approaches, so lucky observers might see rates approach 100 meteors per hour.

Quadrantid meteors hit Earth's atmosphere at 25 miles per second. The incinerated dust particles apparently derive from debris ejected by the near-Earth asteroid 2003 EH₁.

On the prime meridian

Bisect the Moon's visible hemisphere from north to south pole, and the line would scrape the eastern edge of a trio of prominent craters. Ptolemaeus lies farthest north, just south of



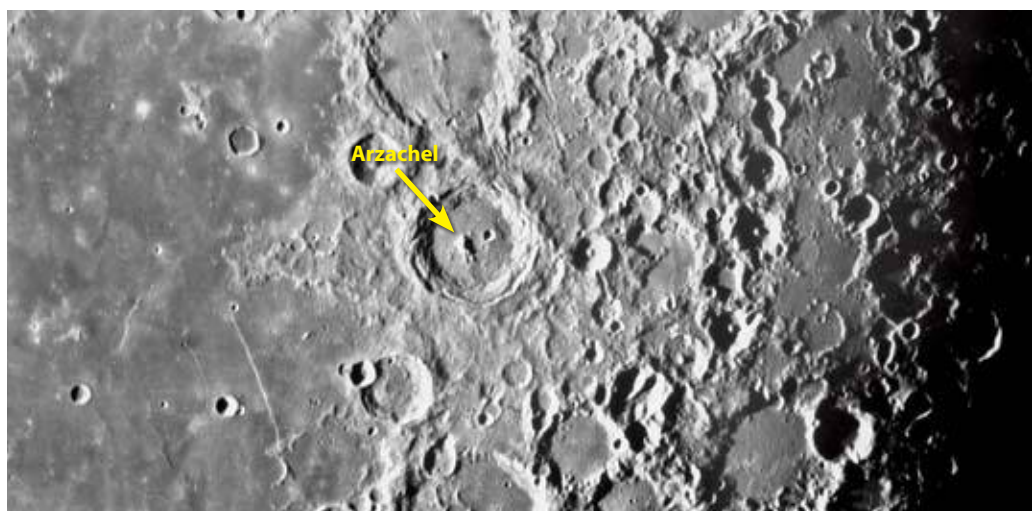
ASTRONOMY: ROEN KELLY

THE QUADRANTID METEOR SHOWER peaks before dawn January 3. With the Moon out of the way then, observers with clear skies should see a great display.

the lunar equator. Next comes Alphonsus, and then this month's highlight, Arzachel.

The three show up nicely even in small telescopes.

Arzachel is the smallest and geologically youngest of this spectacular trio. The 60-mile-wide crater's heavily terraced walls reach higher than those of its two larger neighbors. Two smaller impact craters and an off-center mountain peak dominate the rough crater floor. A distinctive rille cuts across the floor's eastern half and shows up nicely under good conditions. When the Sun sets over Arzachel, the rille projects a long shadow toward the eastern wall. The best views come as the Sun rises over the crater near First Quarter phase (January 6) and as the Sun sets around Last Quarter phase (January 22).



LUNAR CRATER ARZACHEL, with its richly terraced walls and a prominent rille cutting through the eastern part of its floor, is best seen around the quarter phases. FROM CONSOLIDATED LUNAR ATLAS (LPL/UA)

COMETS AND ASTEROIDS

You'll need a telescope and dark skies to pull Comet C/2005 E2 (McNaught) out of the background, but the big rock Vesta will be easy to spot with binoculars from the suburbs.

Cruising the water signs

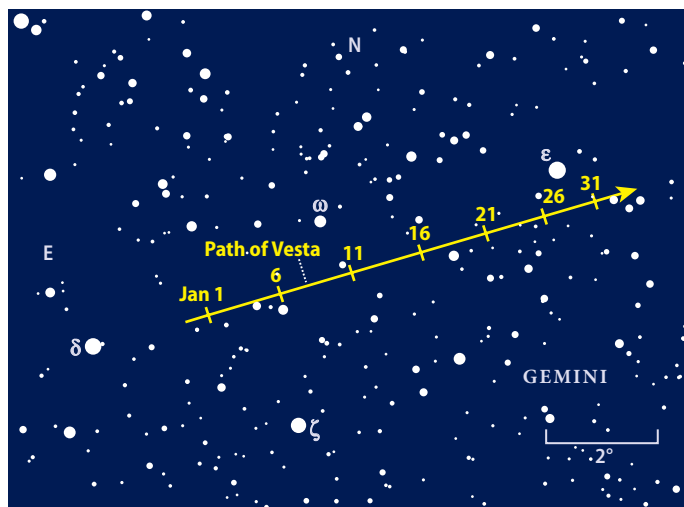
Comet C/2005 E2 (McNaught) remains on a Mars-like orbit this month, like it has for the past several months, plying the ecliptic and edging eastward at a speed that keeps it comfortably ahead of the Sun. This geometry means our viewing angle actually improves in January. As the sky grows dark, Comet C/2005 E2 appears slightly higher in the sky than it did toward the end of 2005.

The modestly faint comet — predicted to glow around 10th magnitude — still has to contend with light pollution, both from the Moon and any city. To get a decent view, wait until after January 16 to get the Moon out of the way, and head out to the country. Comet McNaught glides across the star fields of Aquarius the Water-bearer for most of January

before entering Pisces the Fish toward month's end.

While you're in the area, take a peek at Uranus. The planet lies about halfway between 4th-magnitude Lambda (λ) Aquarii and 5th-magnitude Sigma (σ) Aqr. The planet's tiny disk (3.4" across this month) won't reveal any features, but its conspicuous blue-green color is always an eye-catching treat.

No bright galaxies lie near McNaught's path, so the first faint fuzzy you see will be the comet. Bump up the magnification a bit and take a longer look. The slightly darker sky provided by higher powers will boost the contrast. On January 20, the comet passes 15' south of NGC 7351, an obscure 12th-magnitude galaxy. For images of comet encounters with other deep-sky objects, check out



ASTEROID 4 VESTA reaches opposition and best visibility during January. You should have little trouble picking it out from the background stars of Gemini.

www.aerith.net/pictures/rendezvous.html.

Vesta with only the eyes

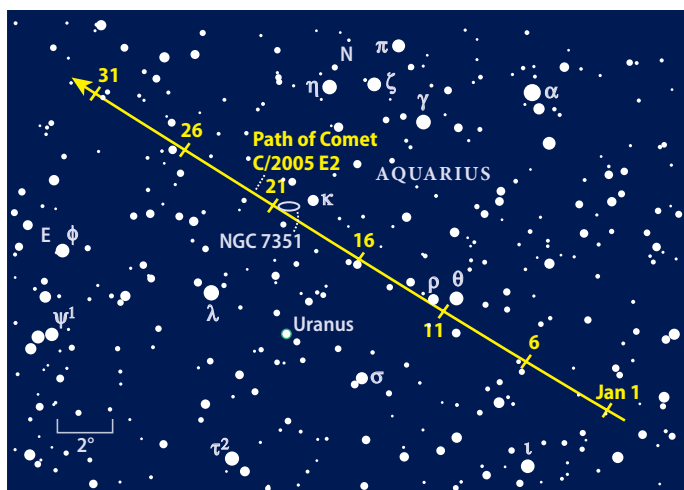
This month, you have a rare chance to see the brightest asteroid without optical aid. Vesta reaches opposition in Gemini January 5, when it glows at magnitude 6.2 — an easy target for binoculars from the suburbs and barely within range of the naked eye at a pitch-black observing site. To find it, point your binoculars about one-third of the way from Delta (δ) to Epsilon (ϵ) Geminorum. The second-brightest dot you'll see is Vesta.

With a diameter of about 320 miles, Vesta is the third-largest asteroid in the main asteroid belt. It has one of the most reflective surfaces of the bunch. An average piece of the

Moon's surface actually reflects much less light — it appears white only because it is so bright overall.

One 5th-magnitude star lies between Delta and Epsilon Gem, along with a handful of 6th-magnitude stars. To be sure you've found Vesta, make a quick sketch of the positions of 4 or 5 stars and check back a day or two later to identify the interloper. Then, if you're under a dark sky, see if you can spy Vesta with your naked eyes.

Vesta is the only asteroid on good display this month. The next best, 3 Juno, glows 2 magnitudes fainter. You can find it in the shield of Orion, where it is nicely placed in the evening sky. The slowly moving asteroid passes within a degree of 4th-magnitude Pi⁵ (π^5) Orionis between January 20 and 26. ■



COMET C/2005 E2 (McNAUGHT) should glow around 10th magnitude this month as it makes its way across northern Aquarius and into Pisces. ASTRONOMY: ROEN KELLY

A field guide to other worlds

From hot Jupiters to pulsar planets, our Milky Way brims with strange worlds.

/// BY RICHARD TALCOTT; ILLUSTRATION BY LYNETTE COOK



◀ **HD 149026** This Saturn-mass planet has a huge core that contains three-quarters of its weight.



◀ 47 URSAE MAJORIS
This system has two planets with masses and orbits close to Jupiter's.



▲ **6 CYGNI B**
This planet orbits one of the two **unlike** **eV** stars that form a **wide** **binary** **system**.



▲ **uPSI ON** **NDROMES** This was the first multi-planet system found around a normal star.



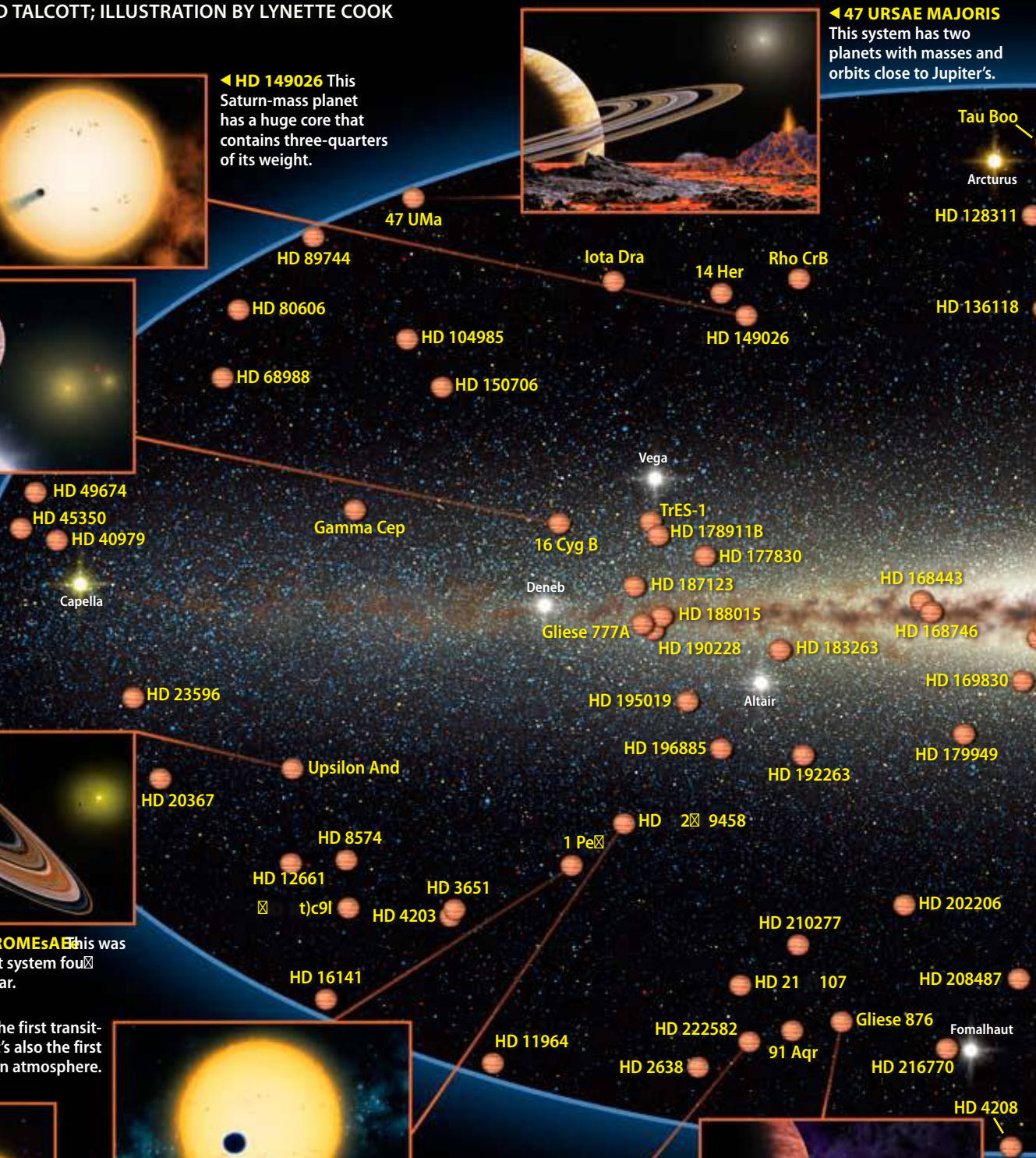
◀ 51 PEGASI The first planet found around a Sun-like star is a “hot Jupiter” — a gas giant near its star.



► **D 222582** hi☒ plan orbit would range from Mercury to the asteroid belt in our system.



▲ **GLIESE 876** The first planetary system found around a red dwarf, its smallest world weighs just 7 Earths.





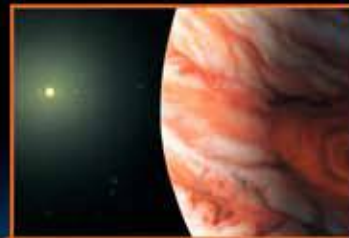
◀ **70 VIRGINIS** This planet weighs 7 Jupiters and has an eccentric orbit.



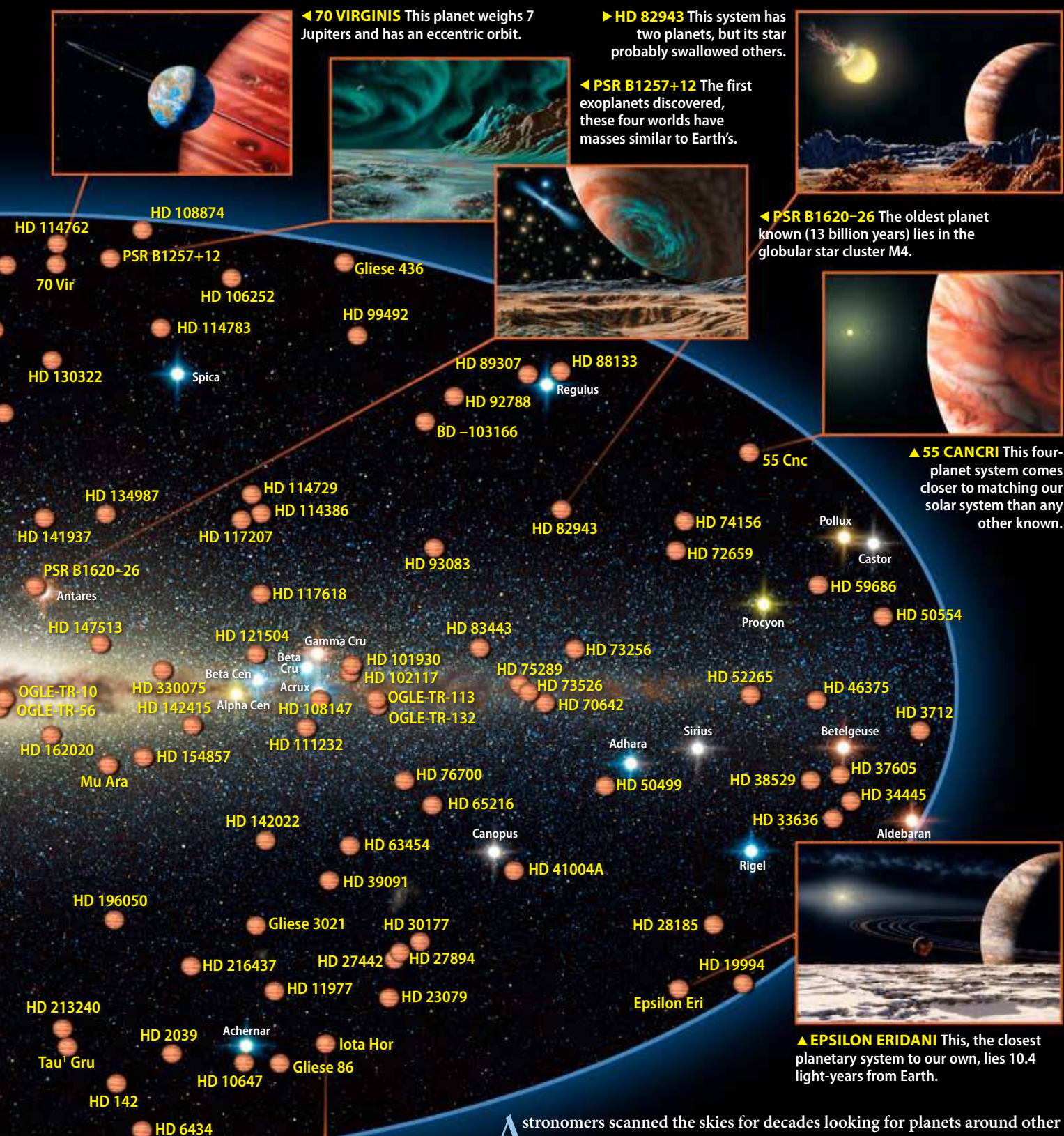
◀ **PSR B1257+12** The first exoplanets discovered, these four worlds have masses similar to Earth's.



◀ **PSR B1620-26** The oldest planet known (13 billion years) lies in the globular star cluster M4.



▲ **55 CANCRI** This four-planet system comes closer to matching our solar system than any other known.



◀ **IOTA HOROLOGII** This planet has an earthlike orbit, but its star appears younger and more active than the Sun.



▲ **EPSILON ERIDANI** This, the closest planetary system to our own, lies 10.4 light-years from Earth.

Astronomers scanned the skies for decades looking for planets around other stars. The searches proved futile until 1992, when Aleksander Wolszczan and Dale Frail found a system of planets around a pulsar cataloged as PSR B1257+12. Three years later, Michel Mayor and Didier Queloz discovered a Jupiter-size planet orbiting a normal star, 51 Pegasi, every 4.2 days.

Although these first two planetary systems were totally different from each other, they shared one important characteristic: They were nothing like what astronomers imagined. Basing their ideas on our own solar system, researchers expected small, rocky planets close to their parent star and big, gaseous planets far away. Nature has other ideas, however. The 150-plus planets now known have given astronomers a rich mix of weird — and not so weird — worlds to explore. ■

DEEP-SKY OBSERVING

On a brisk winter night, the Orion Nebula beckons astronomers and observers alike. /// BY RAYMOND SHUBINSKI

View the sky's greatest nebula

The Orion Nebula (M42) is so named because it lies within Orion the Hunter, a constellation that dominates the winter sky. To find the nebula, look below Orion's belt where his sword hangs. Your eyes alone will see the entire thing as a fuzzy. Binoculars help, but also reveal more

fuzz. Look through a telescope, however, and you'll never forget it. For here lies one of the showpiece celestial objects — a stellar nursery that, after being observed for hundreds of years, still has a lot to reveal.

Stellar neighborhood

The Orion Nebula's position in our galaxy is well known. If we could view the Milky Way from above, it would appear as a vast pinwheel with five spiral arms. The galaxy

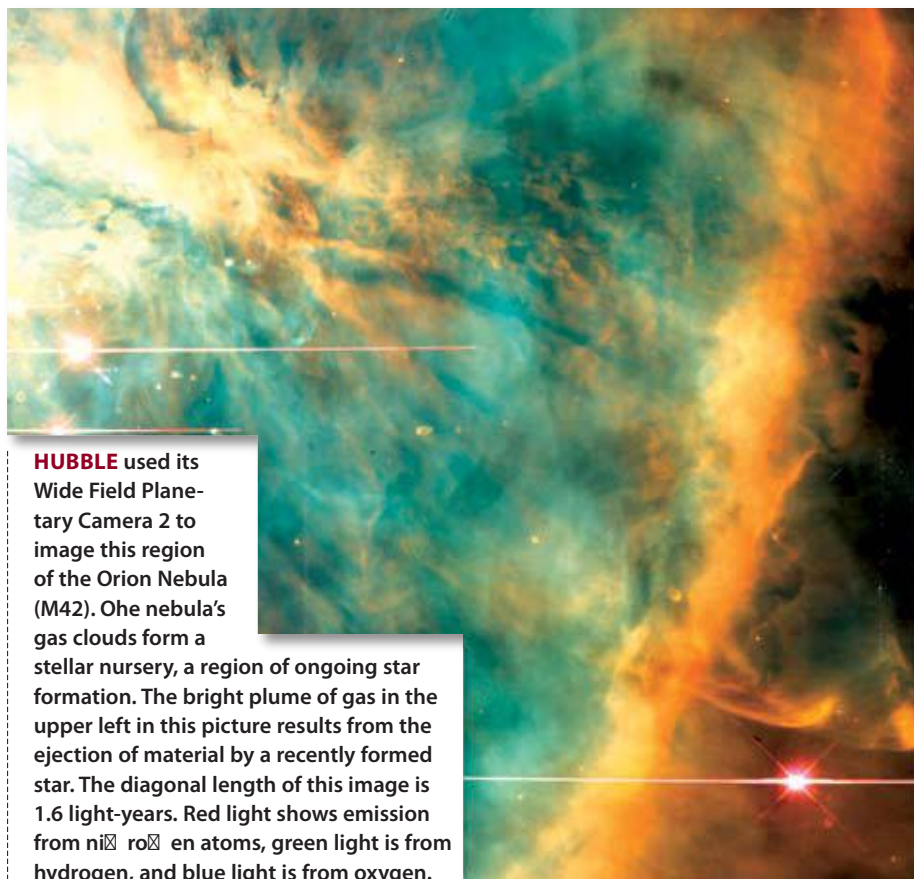
is composed of hundreds of billions of stars and massive amounts of gas and dust. Our solar system resides in the Perseus arm, about two-thirds of the way out from the galactic center.

Our earthbound view is rather different. On a clear summer night in the Northern Hemisphere, the glow of the Milky Way stretches from Cassiopeia in the northeast to Scorpius in the south. From this vantage point, we're looking along the galaxy's rim. Toward Scorpius is the central part of the Milky Way. Rather than seeing a field of blazing stars, our view is obscured by huge clouds of dust and gas.

In the winter, we see the sky opposite the stellar traffic jam found toward the galaxy's center. The winter Milky Way is there, but you need a dark sky to see it with unaided eyes. The winter sky is the brightest of the seasonal skies — it contains the highest concentration of bright stars — and its most famous representative is Orion.

Although the background sky is fainter here than in summer, this area still contains much of the gas and dust that's so prevalent throughout the galaxy. In fact, the Orion Nebula represents only the tip of the proverbial iceberg. M42 is a small part of a huge complex called the Orion Molecular Cloud (OMC). Actually, this complex is divided into OMC-1 and OMC-2. OMC-1 is centered only 1' northwest of the Trapezium — a small cluster at M42's heart — and contains all the visible nebulae. OMC-2 is an infrared and molecular emission source centered approximately 12' north-east of the Trapezium. The OMC is a great

HUBBLE used its Wide Field and Planetary Camera 2 to image this region of the Orion Nebula (M42). One nebula's gas clouds form a stellar nursery, a region of ongoing star formation. The bright plume of gas in the upper left in this picture results from the ejection of material by a recently formed star. The diagonal length of this image is 1.6 light-years. Red light shows emission from ionized nitrogen atoms, green light is from hydrogen, and blue light is from oxygen.



C. R. ODELL/RICE UNIVERSITY, NASA

Raymond Shubinski is the director of Science City/Attractions in Kansas City, Missouri.

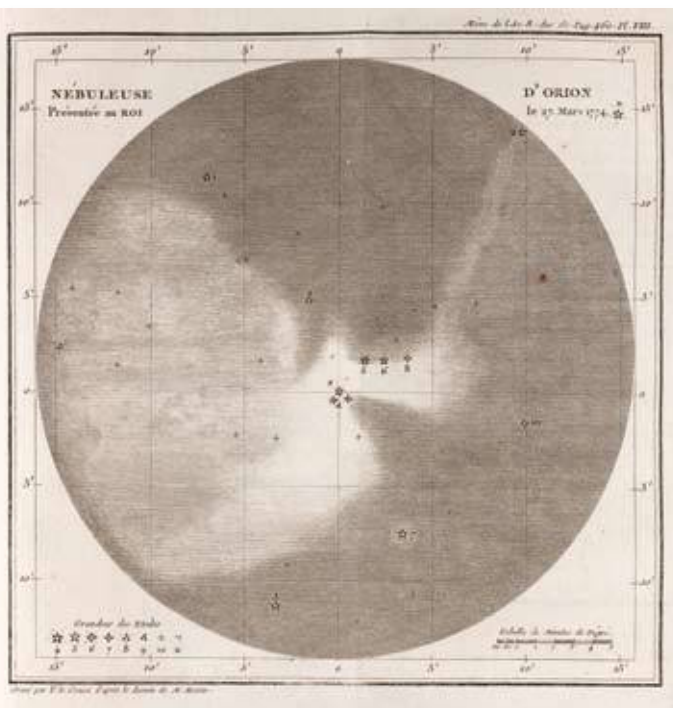
A deep-sky photograph of the Orion Nebula (M42) in a reddish-purple color palette. The nebula is a large, bright, and detailed structure with a central glowing region and intricate filaments and knots of gas. It is surrounded by a field of stars of various magnitudes. The image is a digital composite of two 45-minute exposures on hypered 120-format Kodak PPF Pro 400 film.

AMATEUR ASTRONOMERS
find the Orion Nebula (M42)
irresistible. It's large, bright,
and detailed. Las Vegas astro-
photographer George Gre-
aney shot it with his 6-inch
Astro-Physics EDF apochro-
matic refractor at f/7. This
image is a digital composite
of two 45-minute exposures
on hypered 120-format
Kodak PPF Pro 400 film.



LINDA HALL LIBRARY OF SCIENCE, ENGINEERING, AND TECHNOLOGY

THE FIRST PRINTED REPRESENTATION of the Orion Nebula appeared in 1659 in Christiaan Huygens' *Systema Saturnium*. This book is famous, however, because in it, Huygens correctly explains the nature of Saturn's rings.



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THE DESIGNATION M42 comes from French astronomer Charles Messier, who made a list of 109 objects that looked comet-like through his small telescope. Messier's sketch of his 42nd object appeared in *Mémoires de l'Académie Royale*, 1771.

/// "I SAW IT FIRST"

The credit for the first telescopic identification of the Orion Nebula should go to Italian astronomer Nicholas Peiresc, who made notes in 1610. They remained unpublished for many years, and Jesuit priest Johann Baptist Cysat "rediscovered" the fuzzy patch in 1618.

The bulk of the credit probably should go to Dutch astronomer Christiaan Huygens. Born in 1629, Huygens' list of accomplishments is breathtaking: He developed the pendulum clock, invented the balance wheel for

mechanical watches, and formulated a wave theory of light.

Huygens was also an avid observer who used several long-focal-length refracting telescopes. In his 1659 book, *Systema Saturnium* (in which he correctly identified the nature of Saturn's rings), Huygens published the first drawing of the Orion Nebula.

Near the end of the 18th century, English astronomer William Herschel turned one of his first telescopes on this cosmic wonder. Herschel continued to

observe M42 and to build bigger and better telescopes, which culminated with a scope containing a 40-inch mirror. This instrument gave bright, detailed views of celestial objects, but was hard to maneuver. The Orion Nebula was the last object Herschel viewed through this telescope before he retired the ungainly beast.

French comet-hunter Charles Messier was the one who really put the Orion Nebula on the map. In 1758, Messier spotted what would become known as

the Crab Nebula. He made it the first entry — M1 — in his now-famous catalog of deep-sky objects. By 1769, Messier had developed a list of 41 objects, which he wanted to publish.

To wrap up the project, Messier added four additional objects: the Orion Nebula (M42), a separate part of the Orion Nebula (M43), the Beehive open cluster (M44), and the Pleiades (M45). Messier's list eventually totaled 109 objects, but few capture amateur observers' interest like number 42. — R. S.

star-forming region that envelops all of the constellation Orion and more.

Observing M42

Today, just as in the time of William Herschel, getting a new telescope means taking a look at the Orion Nebula. It represents a benchmark to which we can compare other deep-sky objects. Nineteenth-century

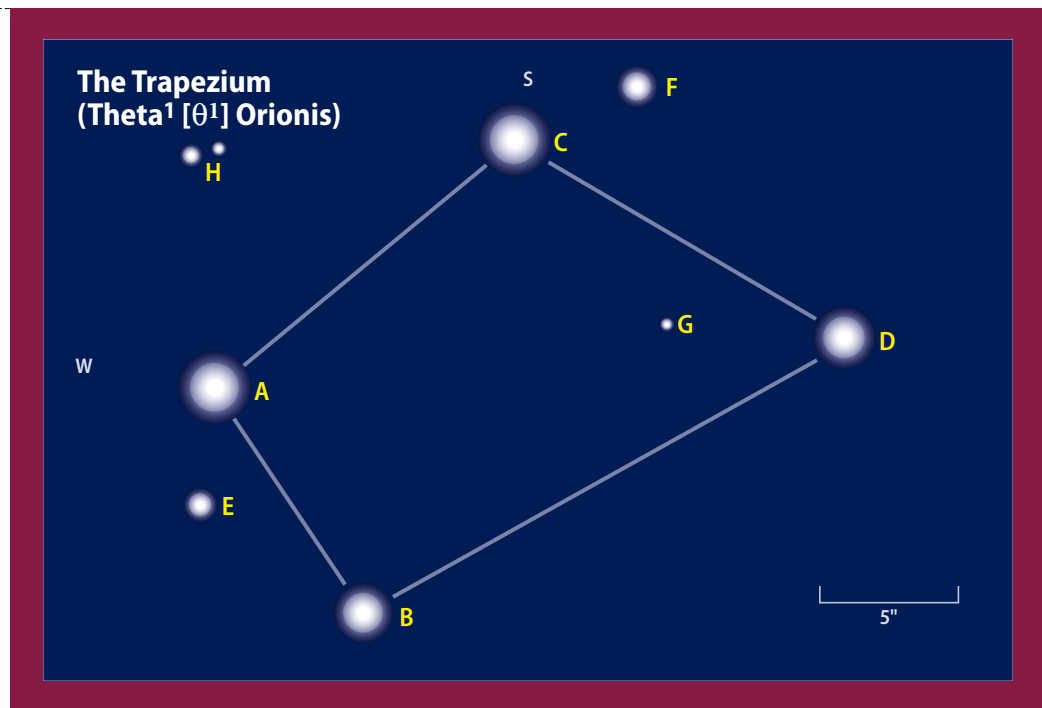
astronomy popularizer Garrett P. Serviss noted the middle star in the sword — Theta¹ (θ¹) Orionis — resolves into the famous Trapezium even in the smallest of telescopes. He described it as an "irregular square shining in a black gap in the nebula."

To the unaided eye, the Trapezium appears as a single star. When viewed through a telescope at low power, the "star"

splits into four — designated, from west to east, as A, B, C, and D, with C being the brightest. A larger telescope and higher magnification reveal two more (E and F), and the largest amateur scopes may show G and H (which comprise a double star).

English observer William Henry Smyth in his famous *Cycle of Celestial Objects* (1844) refers to the nebosity around the

THETA¹ (θ¹) ORIONIS, the middle star in Orion's sword, shines at magnitude 4.2. When seen through a small telescope, however, it resolves into four stars called the Trapezium. The stars A, B, C, and D received their designations according to their right ascensions, not their brightnesses. Star A shines at magnitude 6.7, B at magnitude 8.0, C at magnitude 5.1, and D at magnitude 6.7. If your sky is steady, an 8-inch scope may reveal 11th-magnitude E and F. You probably will need a 14-inch telescope to find G and H, which both glow faintly at 15th-magnitude.



ASTRONOMY: ROEN KELLY

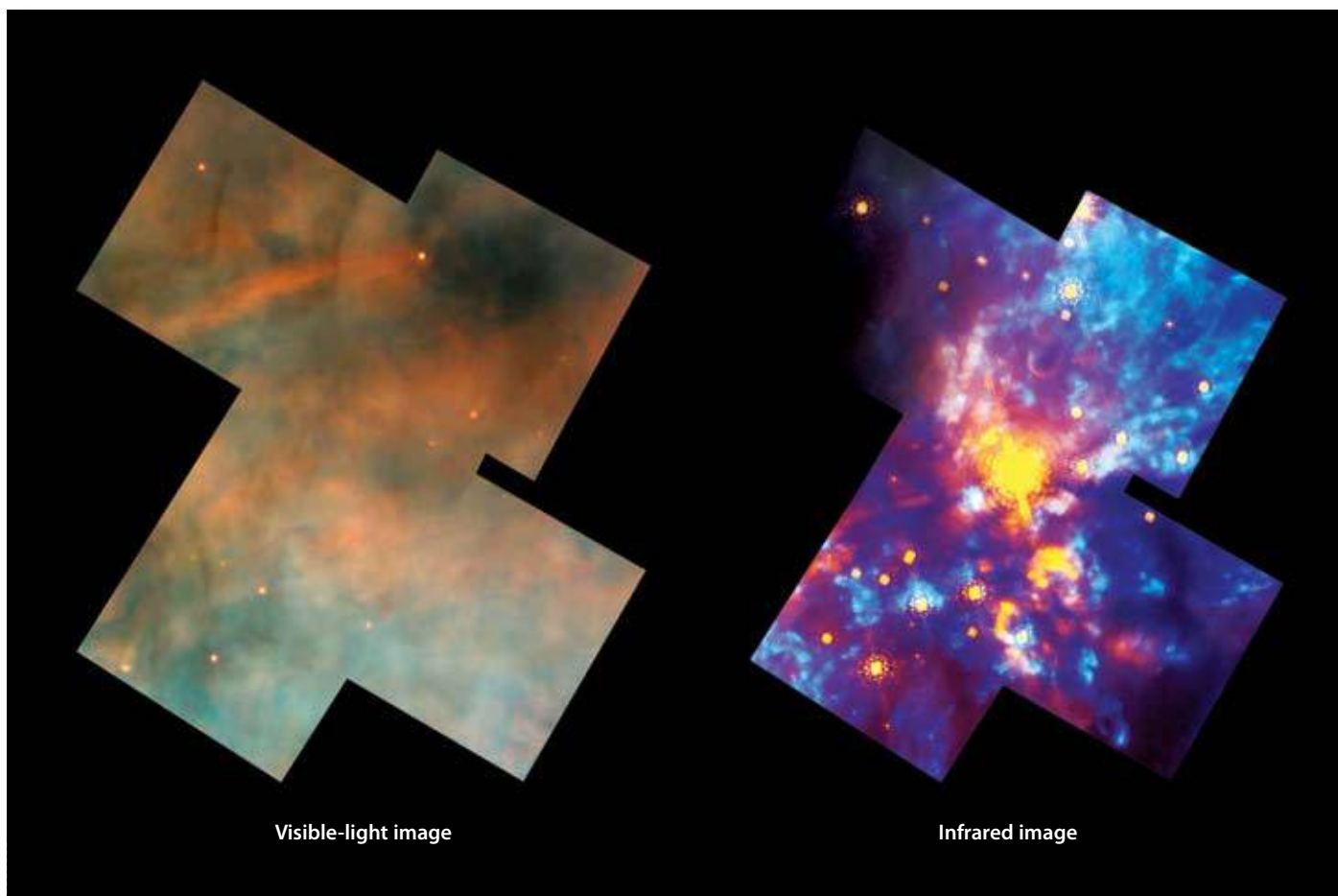


MICHAEL E. BAKICH COLLECTION

THIS PAIR OF SKETCHES of the Orion Nebula appeared in *Account of the Great Nebula in Orion*, Harvard College Observatory Annals, vol. 5, 1867. The volume's author created the frontispiece (right) based on numerous observations. The author's son, William C. Bond, sketched the nebula (above), emphasizing its extent and contrasting areas.



MICHAEL E. BAKICH COLLECTION



Visible-light image

Infrared image

STScI/NASA

TWO VIEWS OF M42 show why astronomers image celestial objects in different wavelengths. The Hubble Space Telescope's Wide Field and Planetary Camera 2 created the image on the left. Hubble's Near Infrared Camera and Multi-Object Spectrometer made the one

on the right. It reveals the Orion Nebula as an active star-formation region where stars and dust glow yellow-orange and hydrogen clouds appear blue. The diagonal extent of each image is about 0.4 light-year.

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GALILEO AND M42

Why didn't Galileo record the Great Nebula in Orion? We might understand how he could overlook a faint outer planet, but how could he have missed a fuzzy patch visible to the naked eye? As always, reality is more

complex than it seems at first glance. Flandrau Planetarium in Tucson, Arizona, has displayed an exact replica of one of Galileo's telescopes for many years. One look through this primitive instrument (mounted so visitors

can view with it), and you'll realize just how incredible his discoveries were.

Galileo made his first telescopes while living in Venice. The "figure" of the glass lenses was done by trial and error, and

the glass may have been full of air bubbles. Perhaps Galileo thought the fuzzy nature of the region in Orion's sword had more to do with his instrument than with the true nature of the object. — R. S.

Trapezium as the Fish's Head. Other early observers also noticed this aquatic similarity. Sir John Herschel, son of William, compared the nebulosity "to a curdling liquid or a surface strewn over with flocks of wool."

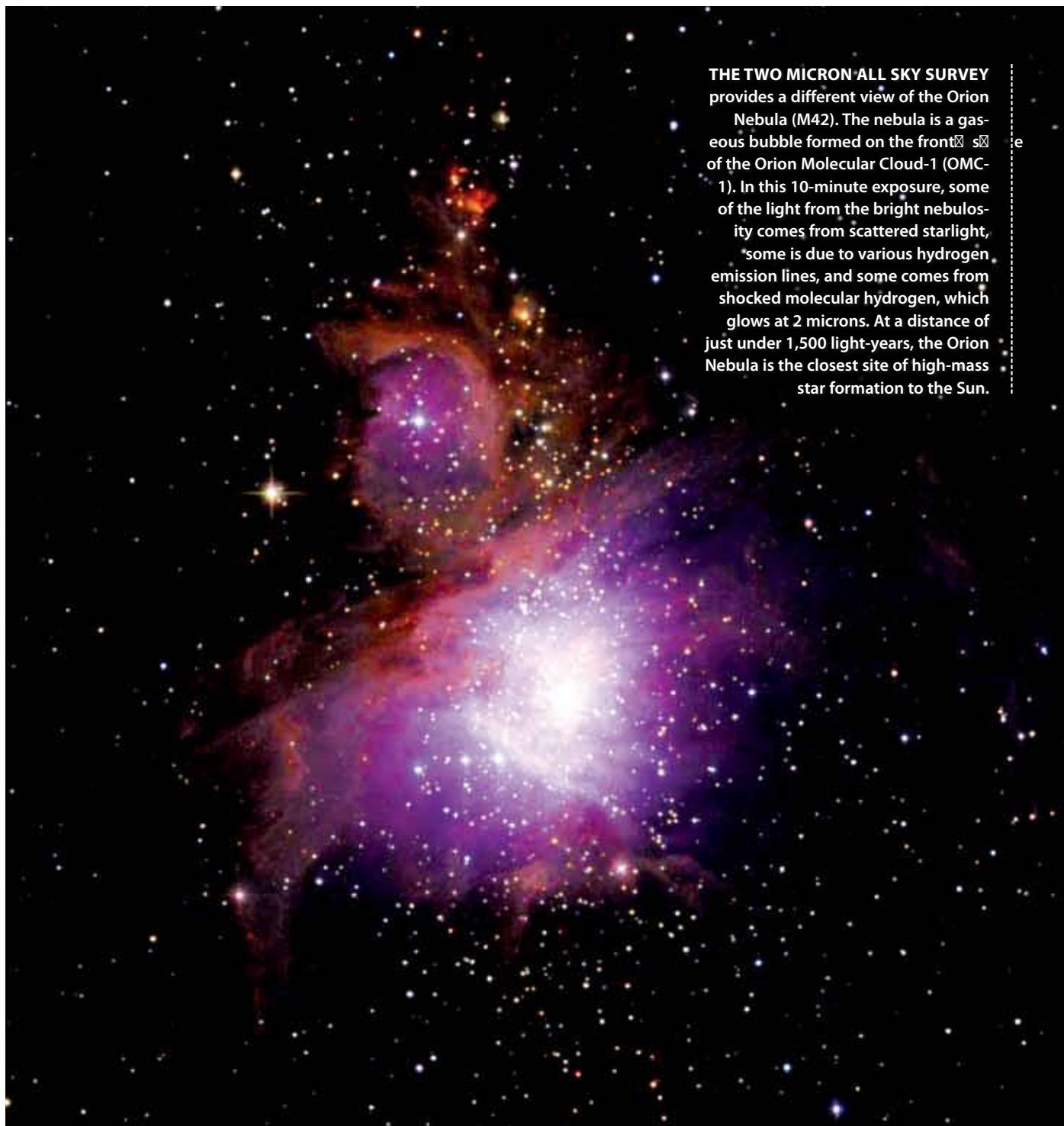
Despite what Hubble Space Telescope images or even photographs taken by amateur astronomers show, it is difficult to see colors in the nebula. Through telescopes,

some observers have reported a hint of green or purple in the clouds surrounding the central stars.

Before photography, capturing an image of the Orion Nebula depended on a skilled observer with a keen eye and an artistic hand. Dutch astronomer Christiaan Huygens' early drawing shows only a smudge with an indentation and three stars. M42

drawn by French comet-hunter Charles Messier is detailed and clearly shows the visual impression left by the nebula.

Photography was invented in the 1830s but was cumbersome. Before the first photographic image of M42 was captured, American astronomer George Phillips Bond produced a drawing of M42 that ranks as the most beautiful and detailed



THE TWO MICRON ALL SKY SURVEY provides a different view of the Orion Nebula (M42). The nebula is a gaseous bubble formed on the front edge of the Orion Molecular Cloud-1 (OMC-1). In this 10-minute exposure, some of the light from the bright nebula comes from scattered starlight, some is due to various hydrogen emission lines, and some comes from shocked molecular hydrogen, which glows at 2 microns. At a distance of just under 1,500 light-years, the Orion Nebula is the closest site of high-mass star formation to the Sun.

2MASS/MOSMAG IMAGE CONSTRUCTION BY E. KOPIK

ever made. Bond was the director of the Harvard College Observatory during the American Civil War and used observations of the Orion Nebula through a 15-inch refractor over many years to render this detailed image. The original drawing still hangs at Harvard University.

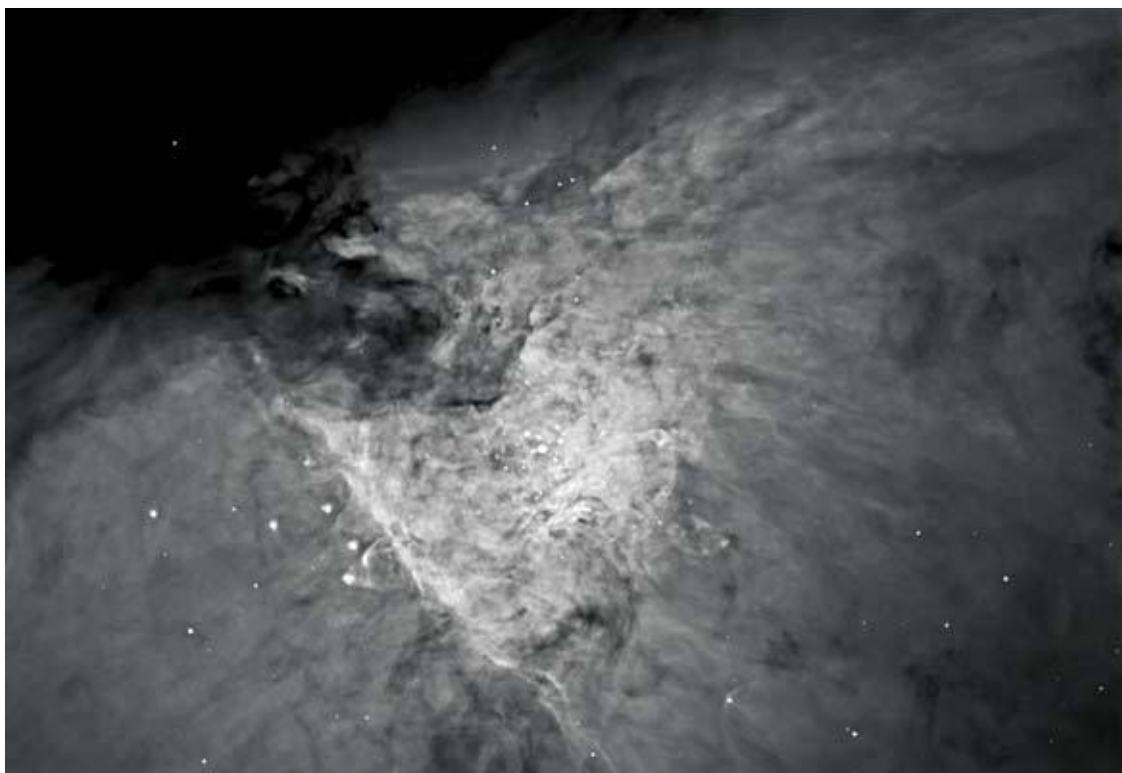
American astronomer Henry Draper captured the first photographic image of

the Orion Nebula September 30, 1880.

Draper used an 11-inch Alvan Clark refractor with a triplet objective. He also used a new “dry-plate” photographic technique to make his images. The exposure lasted 50 minutes. Since that night in 1880, M42 has been scrutinized through every size telescope and in every available band of the electromagnetic spectrum.

Inner turmoil

The Orion Nebula is about 1,400 light-years away and more than 10 light-years across. Yet it represents only a small part of the great Orion Molecular Cloud. The cloud contains a mixture of cold hydrogen and dust grains. M42 is known as an emission nebula. The hydrogen is excited by the hot stars buried within. Excitation is a



ADAM BLOCK/NOAO/AURA/NSF

M42 LOOKS STRANGE when imaged through a Hydrogen-alpha (H α) filter. H α is red light with a wavelength of 656.28 nanometers created when a hydrogen atom absorbs energy and re-emits it. Common H α images show solar flares and prominences on the Sun. But, as this image shows, nebulae also emit H α light. This H α image (a single 105-minute exposure) was taken through a 20-inch RC Optical Systems Ritchey-Chrétien reflector at f/8.4 using an SBIG ST-10XME CCD camera.



INFRARED PROCESSING AND ANALYSIS CENTER, CALTECH/JPL

THE FAMILIAR CONSTELLATION ORION looks different in infrared wavelengths. This false-color image was constructed from data collected by the Infrared Astronomical Satellite (IRAS) and covers 30° by 24°. The bright yellow region to the lower right is Orion's sword, which contains the Orion Nebula (M42). Betelgeuse (Alpha [α] Orionis) shines at the upper center.



PAT AND CHRISTIE/ADAM BLOCK/NOAO/AURA/NSF

M43 IS PART of the much larger Orion Nebula complex, and it lies roughly 10' north of M42. This section features a hot, bright star (center) that is ionizing the gas near it. This creates a sphere of glowing hydrogen, which appears pink. This image was shot through a 20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4 with an SBIG ST-10XME CCD camera. Three 20-minute exposures through red, green, and blue filters were combined to produce the final image.

process by which hydrogen atoms absorb energy (from nearby stars). The atoms can't hold the energy for long, however, and quickly release it as light.

The Orion Nebula is a hotbed of star formation. The stars in and near the Trapezium are young — possibly only 300,000 years old. Theta¹ (θ^1) C Orionis contains 40 times the Sun's mass and has a surface

temperature of 40,000 K (72,000° F). Because of its size and mass, Theta¹ C produces tremendous amounts of ultraviolet radiation, which causes nearby gas clouds to fluoresce. Theta¹ C is 210,000 times brighter than the Sun, and it produces a stellar wind that blows at 5.7 million mph (9.2 million kilometers/hour). This tremendous wind is blowing planet-forming dust

particles away from the surrounding stars, making it impossible for planets to form.

Conditions within the Orion Nebula are incredible. In *The Perfect Storm* by Sebastian Junger, two massive atmospheric fronts collide over the Atlantic Ocean to create killer waves. A perfect storm of cosmic proportions is taking place in the Orion Nebula. Disks of dust and gas surround smaller,

Greek mythology provides many stories about Orion. One myth says Orion was placed in the sky as a punishment for his arrogance. Another declares Orion was in love with the beautiful goddess Diana. Diana's brother, Apollo, was enraged by this relationship and tricked Diana into killing Orion with one of her arrows.

Another story claims Orion threatened to kill all animal life on Earth. To prevent this, the Earth goddess, Gaia, sent a scorpion that stung Orion on the heel, killing him. Regretting her actions, Gaia placed Orion opposite Scorpius the Scorpion in the sky so Orion could never be harmed again. Any star chart shows this arrangement.

The ancient Egyptians saw Orion as the god Osiris, the husband of Isis. Seth killed his brother Osiris in an ancient rivalry. To make certain the job was complete, Seth chopped Osiris into 14 pieces and scattered them throughout Egypt.

Isis recovered all but one part and placed Osiris in the sky where he could be seen by all. Osiris became a pre-Christian symbol of death and resurrection because Orion sets in the springtime

when crops are being planted and reappears when the crops have been harvested.

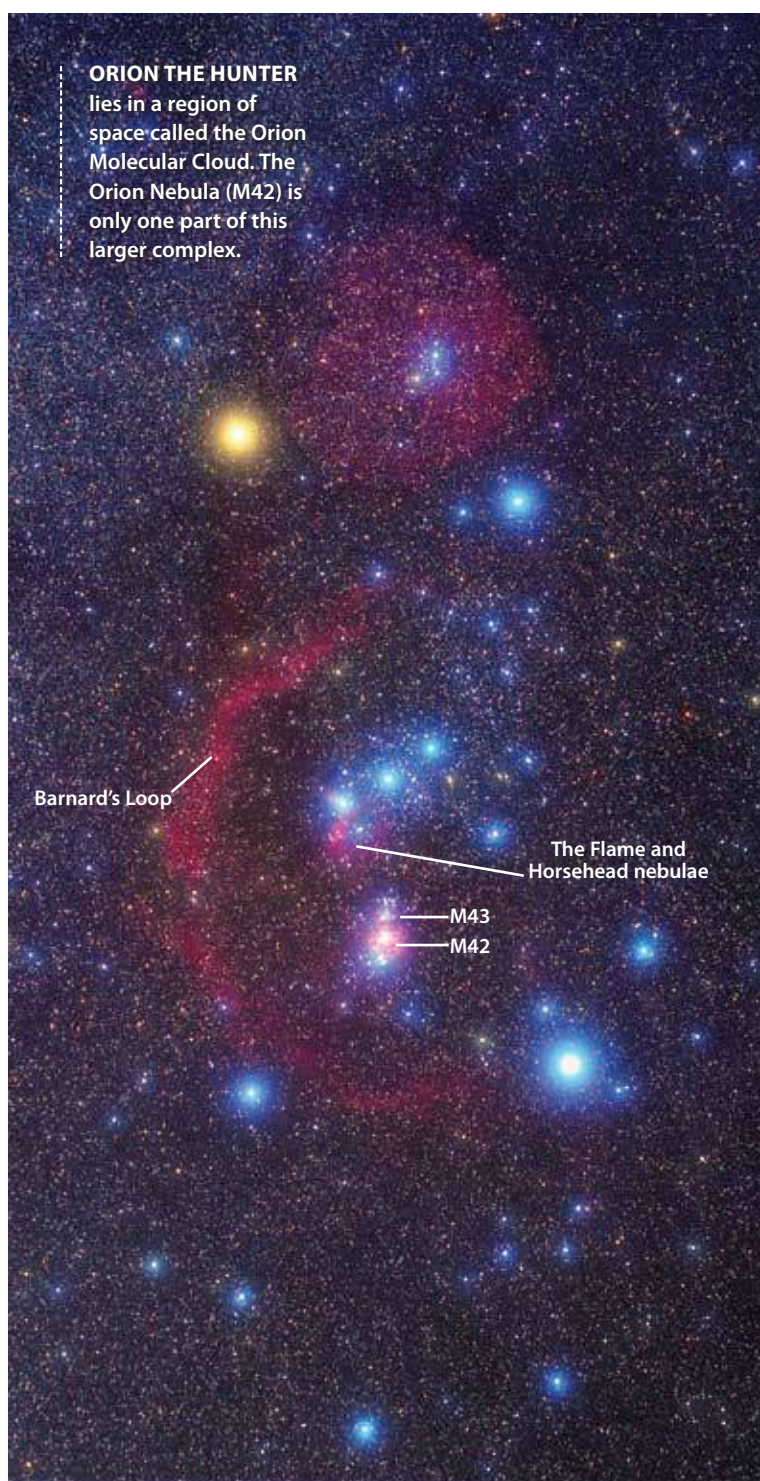
The Greeks told similar stories emphasizing Orion's timekeeping nature. The poet Aratus wrote a book, *Phaenomena*, around 200 B.C. The long poem is really a calendar guide that gives directions about nature and the passage of the year. Even T. H. White captures Orion's calendric use in his book *The Sword in the Stone* when he has the young Wart — the future King Arthur — looking through a castle window at Orion, hoping for spring. Perhaps Wart looked at the giant's gleaming sword and thought of Excalibur.

As Greek and then Roman civilization collapsed, the growing power of Islam flowed from the deserts to fill the void. Muslim scholars collected Greek manuscripts and translated them into Arabic. This preserved a great part of ancient literature and science.

To these scholars, Orion became Al Jabbar, the mighty giant. From a contemporary view, this gives a good idea as to what heights basketball superstar Kareem Abdul-Jabbar must have aspired.

— R. S.

ORION THE HUNTER lies in a region of space called the Orion Molecular Cloud. The Orion Nebula (M42) is only one part of this larger complex.



low-mass stars within the nebula that also produce stellar winds. The supersonic stellar wind of Theta¹ C collides with the stars' winds, producing the perfect cosmic storm. This storm will continue as long as the supermassive star continues to produce energy. If we could run time forward even a million years, we'd see Theta¹ C obliterate itself in a supernova.

No matter how much we know about the physical nature of this complex region, it never fails to delight when seen for the first time or after many years.

When first shown Orion, children relate the shape of this constellation to a bow tie, an hourglass, or even a butterfly. In the latter case, the great nebula marks one of the colorful spots on its wing.

However you see this giant of a constellation, it's filled with wonders beyond imagination. Nearby and just above M42, one can find M43. Above M43 is another region of nebulosity containing the Running Man Nebula (NGC 1973–5–7). Still, the complexity of the Orion Nebula and the surrounding area only hints at the beauty and drama of our galaxy. ■

Ask Astro

When neutron stars collide, stellar densities

WHEN NEUTRON STARS COLLIDE

What would happen if two neutron stars, each traveling at 90 percent the speed of light, struck each other head-on? — CHRISTOPHER PERISIE, CHELSEA, MASSACHUSETTS

Neutron stars are the smallest stars known. Although astronomers still don't know how big they are — measuring the size of such small objects at astronomical distances is incredibly difficult — they believe neutron stars are no more than 20 miles (32 kilometers) across. A chance collision between two stars this small is extremely unlikely in the vastness of space. It's possible only in a region of high stellar density, such as a globular cluster. Even there, you might have to wait 100 million years to see such a calamity.

On the other hand, if two neutron stars form a close binary system, then their orbits will slowly shrink. Unless a third star disturbs the system, the neutron stars will ultimately collide. A neutron-star binary system can form if both massive stars in a normal-star binary system undergo supernova explosions themselves and form neutron stars — as long as the explosions don't disrupt the system. Or perhaps, such systems form in dense stellar environments,

when a neutron-star and normal-star binary pass closely to another such system. The two systems can exchange members.

Astronomers know of six neutron-star binaries, so it appears likely neutron-star collisions do occur in the universe. Usually, astronomers observe one of the neutron stars in the pair as a radio pulsar (and a double pulsar system was recently discovered). Collisions between neutron stars are so violent they have been linked with many energetic phenomena, including gamma-ray bursts.

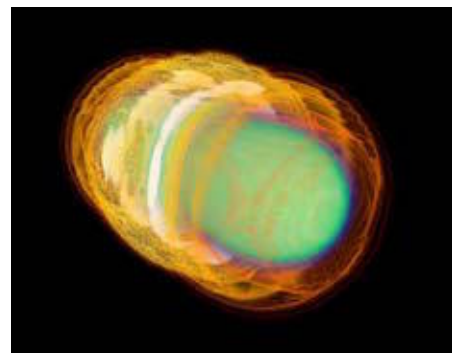
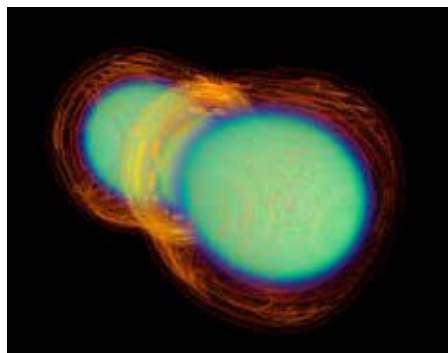
Moreover, the fast, periodic motions that occur as the stars spiral together should generate gravitational waves. Scientists anticipate several current ground-based observatories (including both the Laser Interferometer Gravitational-wave Observatories [LIGO] in Hanford, Washington, and Livingston, Louisiana) may detect these waves. In addition, the first space-based gravitational-wave observatory, Laser Interferometer Space Antenna (LISA), is slated for a 2015 launch and will

look for lower-frequency gravitational waves — those caused by large mergers.

An accurate description of these collisions pushes our theoretical understanding of matter and gravity to the limit. Astrophysicists regard these collisions as theoretical test beds. They allow us to explore how current computational methods hold up under extreme events.

Unfortunately, astrophysicists don't yet know the details of what happens when two neutron stars smack together. A full understanding of the collision uses Einstein's theory of general relativity and the mechanics of neutron stars. Our understanding of the details is still evolving. The outcome likely depends on the density, pressure, and temperature of material within neutron stars' interiors — factors described by the so-called equation of state (EOS). The true properties of superdense neutron-star matter are still uncertain. We do not yet have all the necessary data to run a simulation and see what happens in detail.

Nevertheless, we can sketch out the basics. Such a collision will occur at relativistic speeds, with a total energy approaching 10^{55} ergs — 10,000 times the energy of a supernova. The collision is inelastic,

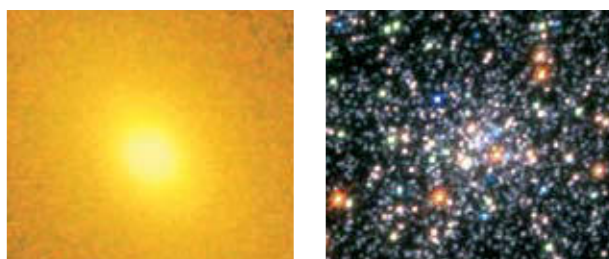


IF TWO NEUTRON STARS, each with a mass of our Sun, collide head-on, their merger will create a flood of energy. In this computer simulation, green and blue correspond to the individual star's energy

density, and orange corresponds to the collision's energy. One such collision is possible on the outskirts of our galaxy in 300 million years. WERNER BENDER/ZUSE INSTITUTE BERLIN/ALBERT EINSTEIN INSTITUTE/WASHINGTON UNIVERSITY

THE STELLAR DENSITY of M32's core (left) is greater than that of globular cluster M15's (right). No telescope can resolve the stars in M32's core because they are so densely packed. But the Hubble Space Telescope can resolve M15's center. The two objects' distances also differ greatly, which is another factor to consider when comparing how well their cores can be resolved. M32 is roughly 2.5 million light-years away, while M15 is in our own galaxy, 30,000 light-years away. This means M32 is about 83 times farther away from us than M15. Both images are 1.6 light-years across.

M32: T. LAUER (NOAO), REPRODUCED BY PERMISSION OF AAS; M15: NASA-STScI-1995-06



ASTRO TERMS

EQUATION OF STATE

A mathematical relationship describing matter's state (solid, liquid, gas, or plasma) under given physical conditions. Usually, the relationship concerns at least two of the following conditions, or variables: temperature, pressure, volume, and energy.

NEUTRINO

Fundamental particle; does not interact by electromagnetic forces; has small mass; three types (or flavors) exist

meaning the objects stick together. Think of two gummy balls slamming together. As the stars touch and merge, a strong shock wave forms within them. Matter streaming through the shock decelerates. Its kinetic energy turns into a huge amount of thermal energy — the material reaches temperatures higher than 500 billion kelvins, compared to the Sun's 5,800 K surface.

The collision rocks the merged object, which probably ripples with large-scale vibrations. These motions should produce gravitational waves. The merger creates a flood of neutrinos and anti-neutrinos. As these particles interact, they will annihilate one another, producing a super high-energy fireball. Recent findings support the connection of short-duration (less than 2 seconds) gamma-ray bursts with such mergers (see News, page 28).

Odds are, such a collision forms a black hole. The maximum mass of a neutron star depends strongly on its rotation mechanics. Because we don't yet know the correct EOS, we don't know how massive neutron stars

can get. Most estimates suggest the combined mass of two typical neutron stars (each roughly 1.4 solar masses) is too high for the merged object to avoid collapsing into a black hole unless the object ejects enough matter during the merger.

If all the kinetic energy converts to heat in the collision, quickly and efficiently, the merged object might avoid collapse for a few seconds. This would allow more particles and radiation to escape — possibly enough for astronomers to detect. Collapse might also be slowed if the merged object spins fast enough. Recent calculations suggest the neutron-star system's dynamics control the merger, which occurs in fractions of a millisecond. If the black hole forms promptly, most of the energy associated with the collision will be sucked down the hole into oblivion.

So, it may be that one of the most extreme events in the universe ends with more of a fizzle than a pop. — **TOD STROHMAYER**, NASA GODDARD SPACE FLIGHT CENTER, GREENBELT, MARYLAND

STELLAR DENSITIES

How close can stars get to each other in galaxy cores? — **DAVID NORBY**

Our Sun sits in a typical region of the Milky Way Galaxy. Our nearest neighbor, Proxima Centauri, lies 4.2 light-years away. The average stellar density here in the galactic disk is one star every 19 cubic parsecs, or about 5 light-years between stars.

As any seasoned amateur observer can tell you, the star density in the center of globular clusters is high. In the densest globular-cluster cores, not even the largest Earth-bound observatories can resolve individual stars.

The Hubble Space Telescope (HST) can do it, though, and it gives astronomers a

chance to determine a core's density with reasonable accuracy. M15's center packs approximately 4 million stars per cubic parsec — that's more than 75 million times denser than the region around the Sun. This works out to an average of only 0.013 light-year, or 860 astronomical units (1 AU is the average Earth-Sun distance), between stars. Most galaxies, such as M31 in Andromeda, M33 in Triangulum, and the Milky Way have central densities close to this value — an average separation of 0.013 light-year.

But some galaxies pack stars even tighter. M32, one of the Andromeda Galaxy's satellites, has the highest measured stellar density of any nearby galaxy — around 20 million stars per cubic parsec in its core! Not even HST can resolve M32's core into individual stars. A typical stellar separation at this density works out to 0.008 light-year, or 500 AU — about 12 times the Sun-Pluto distance — between stars.

Tod Lauer of the National Optical Astronomy Observatory calculated that observers at the center of M32 would find a "night sky" as bright as twilight on Earth.

Even at these high star densities, collisions are rare. Globular clusters have stars in their centers called "blue stragglers," which astronomers think are new, massive stars formed by the collision of two old, lower-mass stars. Fewer than one in every 10,000 globular-cluster stars are blue stragglers, which suggests how rare stellar collisions are even in these extreme environments. — **KURTIS WILLIAMS**, STEWARD OBSERVATORY, TUCSON, ARIZONA

Send your questions via e-mail to:

askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187.

Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

PLANETARY OBSERVING

The ringed planet is now at its best until 2029. Here's how to get the most out of your time at the eyepiece. /// BY MARTIN RATCLIFFE

Saturn spectacular

“No object in the heavens presents so beautiful an appearance as Saturn,” wrote British astronomer Richard A. Proctor in his 1865 book, *Saturn and His System*.

☾ It's still true, and that will be demonstrated this month.

Saturn arrives at opposition — opposite the Sun in our sky

— January 27, rising in the east-northeast just as the Sun sets. Lying 755 million miles (1.2 billion kilometers) away, the ringworld will be brighter and closer to Earth than it will be for decades. Now is the time to see Saturn at its biggest and brightest until 2029.

Despite its distance, Saturn remains a treat to observers thanks to its enormous size (about 9.5 times that of Earth). In fact, the globe of Saturn will be about 20" across — about the same angular size as Mars during its November 2005 opposition. Include the ring system, and Saturn appears more than twice this size.

This year, the ringed planet even excels in binoculars thanks to its position south of M44, the Beehive star cluster in Cancer the Crab. Saturn stands less than a degree from the cluster's center, creating a great opportunity for visual observers and astrophotographers alike.

Saturn's opposition also places it high in the southern sky at midnight, when the sky is darkest. Its high altitude allows Saturn's light to cut through the least amount of Earth's atmosphere. This means the planet's image will shimmer less due to atmospheric turbulence than when it's observed earlier in the evening.

And if you need another reason to brave cold January nights, consider this: Over the following decade, Saturn will be a little farther away with each succeeding opposi-

tion, which means it will appear both smaller and fainter. The difference in apparent size amounts to only a couple of arcseconds, but the brightness change will be more noticeable. The planet's broad, light-reflecting rings are edge-on as seen from Earth in 2009, so they contribute less and less to Saturn's brightness during the next few years.

Pale planet

One of the first things you'll notice about Saturn's disk is it's flattened at the poles by about 10 percent. This is caused by a combination of the planet's gaseous nature and its rapid 10-hour rotation period.

Saturn's atmosphere is relatively bland. While Jupiter-like bands of dark belts and bright zones are visible, as are infrequent spots, these features remain subtle at best. (Consider observing them a challenge.) With a little effort, your eye can be trained to see them — and better yet, determine their relative brightness.

Rank the darkest gaps in the rings as 10 and the brightest 1, then estimate the brightness of each cloud feature between these extremes. Make a rough sketch of the disk, and mark regions of differing intensity with a number. Watch for the rare appearance of white spots.

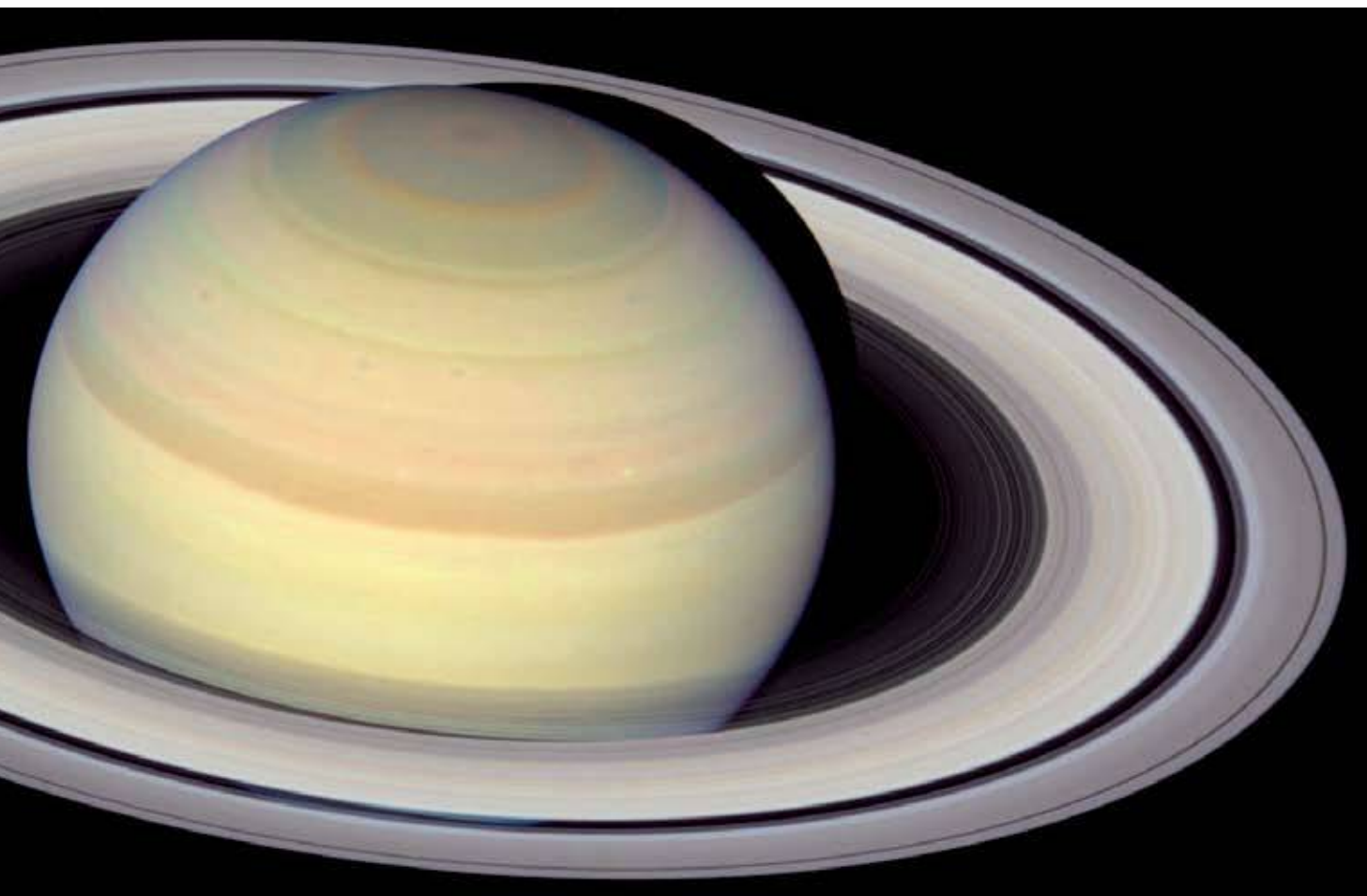
This technique may appear arbitrary, but, long before there were orbiting spacecraft, astronomers were collecting this kind of observation from amateurs all over the world. Slight variations from one observer to another become averaged out — the



advantage of contributing observations to groups such as the Association of Lunar and Planetary Observers (ALPO) and the British Astronomical Association.

What observing equipment best captures Saturn? Julius Benton, who directs ALPO's Saturn Section, says refractor and Maksutov telescopes with apertures of 4 inches or more, and 8-inch or larger Newtonians and Schmidt-Cassegrains, work well for drawing or imaging the planet and its ring system. Scopes in this range are also good for estimating belt and zone intensities.

Martin Ratcliffe, the former president of the International Planetarium Society, coauthors Astronomy's "The Sky This Month."



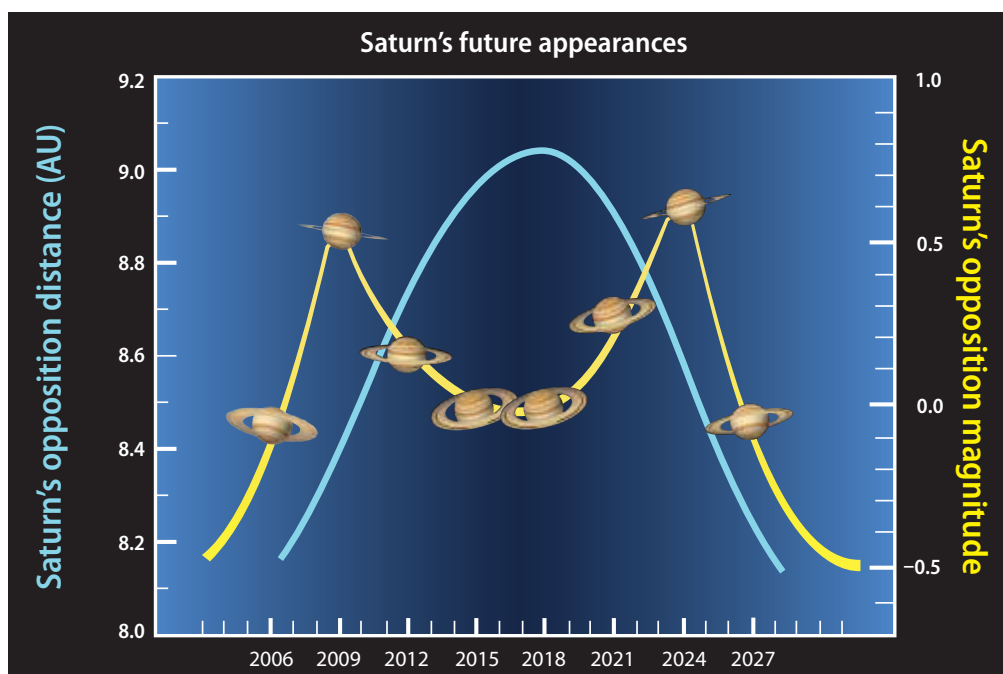
NASA/ESA/ERICH KARRSCHKA (UNIVERSITY OF ARIZONA)



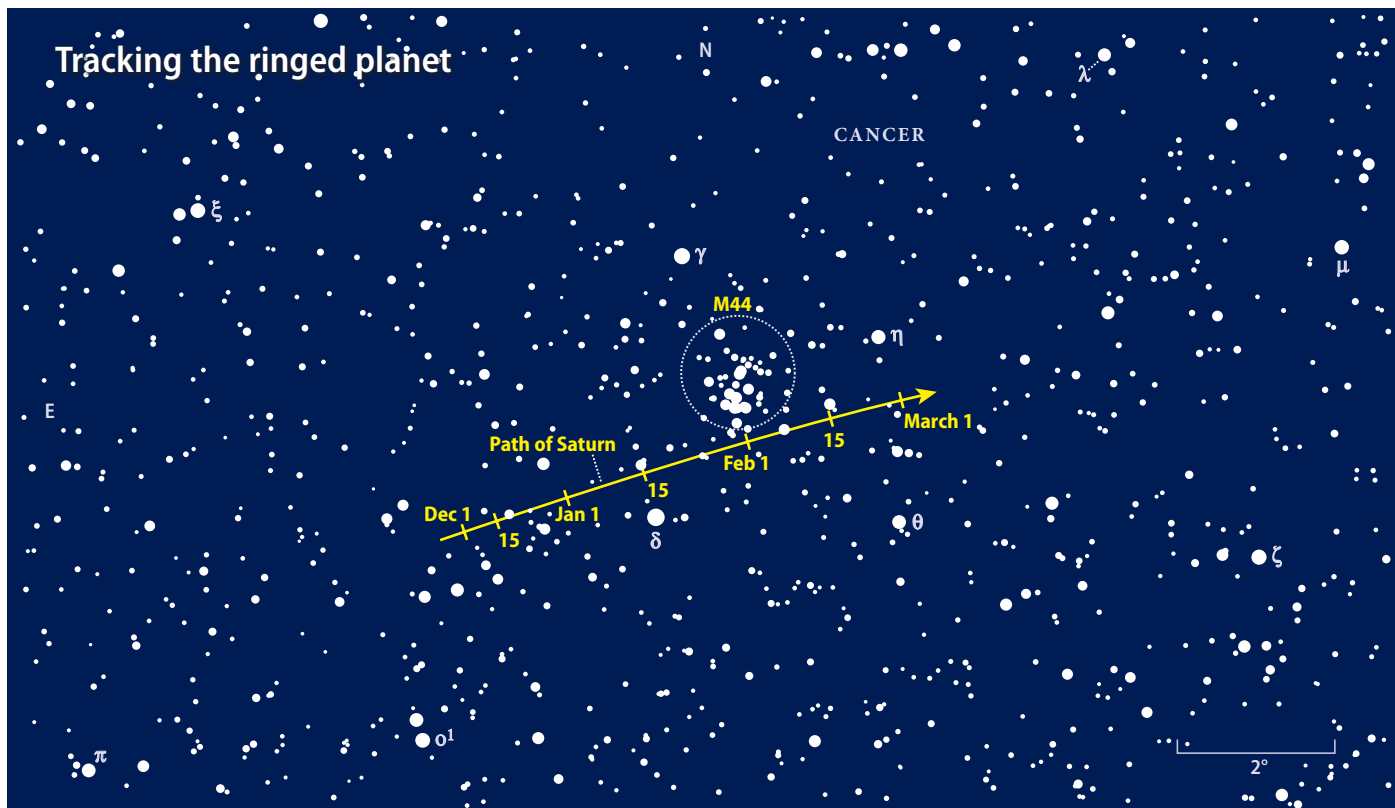
DAMIAN PEACH

/// SATURN CONNECTIONS

Visit the Saturn section of ALPO's web site at www.lpl.arizona.edu/~rhill/alpo/sat.html, or join the organization's Saturn observation e-mail list at groups.yahoo.com/group/Saturn-ALPO for more information. You'll find a comprehensive outline of the types of observations amateurs can provide at the British Astronomical Association's web site, www.britastro.com/saturn, as well. — *M. R.*



Tracking the ringed planet



ASTRONOMY: ROEN KELLY

SATURN BEGINS 2006 near a binocular treat. The ringed planet courses beneath the stars of M44, also known as the Beehive cluster.

For studying Saturn, Benton encourages using standard color eyepiece filters, which enhance the contrast of atmospheric features. Using a red-orange Wratten #23A filter will bring out red and yellow features while darkening bluish ones. With a blue Wratten #38A filter, the reverse happens. Bluish regions appear brighter, and reddish or yellowish belts and zones look darker. A yellow-green Wratten #57 filter improves overall contrast by darkening bluish and reddish belts or zones.

Glorious rings

Three major rings are visible around Saturn with a small telescope. The brightest is the B ring, which is also the thickest as evidenced by the fact that the planet itself cannot be seen through it.

Outside the B ring is the dimmer A ring, which is so thin it can't completely hide Saturn's disk. Billions of icy particles make up Saturn's rings, and we know from spacecraft observations that the "rings" we see through telescopes contain thousands of thin, interacting ringlets.

Between the A and B rings is an easily visible, 2,900-mile (4,700 kilometer) gap called the Cassini Division, after its discoverer, Jean-Dominique Cassini (1625–1712). Despite appearances, this gap isn't entirely

free of icy matter, it just contains much less of it than the bright A and B rings.

Telescopes with apertures of 4 inches or larger will reveal another ring. Discovered in 1850, the gossamer C ring circles Saturn interior to the B ring. The C ring is so transparent, it's nicknamed the "crepe ring."

Many moons

Saturn's satellite retinue offers a multitude of observing pleasures — from a slow-moving outer moon that varies in brightness, to the fast-paced inner moons that change relative positions within an hour.

Topping the list is Saturn's largest and brightest moon, Titan. Site of the farthest spacecraft landing in history, Titan glows at magnitude 8.3 and orbits Saturn in 16 days. Be careful not to confuse Titan with stars, a particular problem with the Beehive cluster so close.

The Cassini spacecraft is revealing fascinating details about Saturn's moons. The most surprising is the recent recognition of Enceladus as an active "water world" whose sprays form Saturn's tenuous E ring (not visible in scopes from Earth). Enceladus is one of the many saturnian moons visible in scopes with apertures larger than 4 inches. The satellite glows at magnitude 11.7 and orbits Saturn in 1.4 days.

Tethys, Dione, and Rhea glow at magnitude 10.2, 10.4, and 9.7, respectively. Mimas, closest to the rings, gleams at magnitude 12.9 and should be visible under good sky conditions. It's the gravitational effect of Mimas that clears out material spiraling into the Cassini Division.

Iapetus is a piebald moon. Sweeping around Saturn every 79.3 days, Iapetus' brightness depends on which side of the ringed planet it's on. The moon gleams at magnitude 10.1 when west of Saturn and magnitude 11.9 when it lies to the east. The reason for this odd behavior is that the hemisphere leading the moon's way around Saturn is much darker than the trailing hemisphere. In fact, the two-tone satellite is the highest-contrast body in the solar system. Iapetus fades in January, passing due south of Saturn January 10. The moon reaches its farthest point east of Saturn by January's end.

Saturn is the iconographic planet. This year's favorable opposition presents Saturn at its best. And for those who have yet to point a scope at the ringed planet, that first glimpse will never be forgotten. ■

**ONLINE
EXTRA**

Learn how amateurs can help professionals study Saturn at www.astronomy.com/toc.

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We've been helping people choose the right telescope since 1979. We have the experience (a staff total of over 150 years of experience using and selling telescopes) to help you pick the telescope that fits your needs (and

New 8", 10", and 12" Meade LX90-LNT scopes stock.

Popular **Meade LX90-LNT** 8" go-to Schmidt-Cassegrains now have 10" and 12" big brothers. All LX90 scopes ship from our stock, so we save you shipping time over dealers who must have them drop-shipped from Meade (and if you're in California, we save you the sales tax).

Here are the freight-paid prices on the LX90's shipped from our stock:

8" LX90-LNT	\$1799 ⁰⁰
8" LX90-LNT, w/UHTC	1974 ⁰⁰
10" LX90-LNT	2299 ⁰⁰
10" LX90-LNT, w/UHTC	2474 ⁰⁰
12" LX90-LNT	2999 ⁰⁰
12" LX90-LNT, w/UHTC	3294 ⁰⁰

Level North Technology makes it easier than ever before to line up your

scope on the sky and start observing. Simply tell your LX90-LNT your location or zip code. It levels its optical tube by itself, aims it North, checks the time, then moves to its two alignment stars — *all automatically!* Center the red dot finder on the alignment stars (you also get an 8 x 50mm finder), and start enjoying go-to computerized observing. An LX90-LNT is an easy scope to use, and now it comes in large economy sizes!



Meade 8" LX90-LNT
\$1799
freight paid

Are these great values?

The low prices of these **Konus** telescopes are downright amazing. Consider the optically very nice

90mm **Konusmotor-90 f/11** refractor, to the left. It has a good-quality equatorial mount, a battery-powered motor drive so you can use it anywhere, and two 1.25" Plössl eyepieces. We sell this scope by the dozens, because it's a great value at only \$209!

The **Konusky-200 8" f/5** reflector, above right, has a heavy duty equatorial mount with a steel leg

You bet they are.

tripod, dual-axis DC motor drives, two 1.25" Plössl eyepieces, an 8 x 50mm finder-scope, and a polar axis finder. It's a lot of telescope for the low price of only \$499!

The **Motormax-150 6" Maksutov**, to the right, has the same heavy duty mount and accessories as the 8" reflector.

It's a terrific value at its low price of only \$799, which is well below the cost of other large Maksutovs.



\$499



\$799

A 6" go-to SCT for \$999. Now, that's a good deal.

The **Celestron Advanced Series 6"** Schmidt-Cassegrain gathers 44% more light than a more expensive 5" Maksutov to show you more faint objects, with 20% higher resolution. Its faster f/ratio means a wider field and brighter images, too.

It has an adjustable height tripod with

2" steel legs, heavy-duty equatorial mount, dual motor drives, Starbright XLT multicoatings, eyepiece, finder, and a NexStar computer to find and track over 45,000 stars and objects for you *automatically*.



\$999

Whether red dot or bull's eye, we have a finder for you.

Non-magnifying red dot and bullseye finders seem to project dots and circles of red light on the dome of the sky. They make it easy to aim your telescope or to star hop from object to object.

Like the original Telrad above (we've sold thousands of these), all of our red dot finders come with batteries and bases. We also carry dozen of conventional find-

ers, from 5 x 25mm to 12 x 80mm.

Here's a list of the non-magnifying illuminated finders that we keep in stock:

Burgess , MRF multiple reticle	\$69 ⁰⁰
Celestron , Star Pointer red dot	29 ⁰⁰
Rigel , QuikFinder bull's eye	39 ⁰⁰
TeleVue , Qwik-Point red dot	29 ⁰⁰
Starbeam red dot	205 ⁰⁰
Starbeam red dot for TeleVue only	205 ⁰⁰
Starbeam red dot for SCTs	245 ⁰⁰
Telrad , bull's eye	39 ⁰⁰
Vixen , red dot for Vixen scopes only	79 ⁰⁰

No-guesswork Celestron GPS Schmidt-Cassegrains.

It's easy to find your way around the sky with a new **Celestron CPC**. Just point it at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet or the Moon) and the CPC will find over 45,000 fascinating deep space objects for you at the touch of a button.

You don't have to memorize a star chart to use a CPC. The scope's built-in GPS system and a few anonymous points of light in the sky are all you need.

Celestron CPC Schmidt-Cassegrains are fully equipped with all the features you need to start observing immediately.

8" CPC800, Starbright coatings

8" CPC800X, XLT coatings

9 1/4" CPC925, Starbright coatings

9 1/4" CPC925X, XLT coatings

11" CPC1100, Starbright coatings

11" CPC1100X, XLT coatings



Celestron 8" f/10 CPC800
\$1899

your budget). And, with our seven-figure inventory, we can usually ship you the right scope, right away, from the hundreds of telescopes we stock.

We started **astronomics** over 26 years ago because we loved astronomy,

Serious solar observing for the price of an eyepiece!

For no more than cost of a premium eyepiece, the sub-Ångström hydrogen alpha filter in the **Coronado PST** (Personal Solar Telescope) lets you see the ever-changing drama of solar flares and prominences growing and subsiding before your eyes. It doesn't just show you sunspots,

as do ordinary solar filters.

The PST includes a dedicated 60mm refractor, a built-in sub-Ångström solar filter, a safe Sun finder, and a 1.25" eyepiece. **\$499**



Have had my Burgess Binoviewers for about two weeks now and they are incredible! Last Saturday night our club had an outreach star party at the museum and the longest lines were consistently at

my NexStar 8 GPS equipped with the binoviewers. The people gave spoken! I can always count on Astronomics for consistently great advice and service.

Customer Quote of the Month #166

A binoviewer with eyepieces for only \$199.

Other binoviewers can cost over \$1200 without eyepieces. A **Burgess Optical SCT Binoviewer** costs only \$199, including two eyepieces. Viewing with two eyes through the Binoviewer's multicoated Bak-4 prisms shows you up to 40% more detail than you can see through a single

eyepiece in the same scope.

Designing a binoviewer isn't rocket science, and modern computerized manufacturing makes this one both good and inexpensive. See the 40% you've been missing.



\$199

A William Optics Petzval-type semi-apo for \$448.

Another manufacturer's 4" Petzval apo optical tube costs \$3600 and is worth it. The **William Optics Zeiher 66 Astro** is a 4-lens multicoated 66mm Petzval with an ED glass e-

ment for semi-apo images. It costs only \$448 and is more than worth it.

It has a 2" Crayford focuser, 2" dielectric mirror diagonal, retractable lens shade, and carry case. It's an optically outstanding small scope for travel, birding, and spur-of-the-moment astronomy.



\$448

A Meade LX D75 go-to makes astronomy easy.

You won't spend all of your time hunting for celestial wonders with a go-to computerized **Meade LX D75** reflector, refractor, or Schmidt-Cassegrain.

A few touches on the Autostar computer and your LX D-75 speeds you to any of more than 30,000 stars, planets, and deep space objects, then tracks it for as

long as you want to observe. You spend more of your time looking at celestial objects and less time looking for them with a Meade LX D75.

Each has an adjustable height steel leg tripod, dual battery-operated motor drives, finderscope, eyepiece, illuminated polar finder, and an Autostar go-to computer.



\$899



\$139

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Celestron NexImage captures the solar system for \$99.

The \$99 **Celestron NexImage** CCD camera takes high power full color images of the Moon and planet with any telescope. It sends them to your computer to view live or print out

later. The full color CCD imaging chip in the NexImage has a big 640 x 480 array of 5.4 micron pixels for sharp and clear high-resolution images.

For wider lunar panoramas, the optional \$24.50 NexImage Reducer Lens will double the camera's field of view.



Celestron SkyAlign go-to scopes start at a low \$279.

You don't need to know the Pleiades from Polaris to find your way around the sky with a **Celestron SkyAlign** go-to scope. With Celestron SkyAlign technology, just point your SLT at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet), and the SLT will find the planets and over 4,000 deep space objects for you *automatically*. A few

anonymous points of light are all you need to find your way around the skies.

Celestron SLT no-guesswork go-to scopes are available in these sizes:

NexStar 60, 60mm refractor

NexStar 80, 80mm refractor

NexStar 102, 102mm refractor

NexStar 114, 114mm reflector

NexStar 130, 130mm reflector

Each has two eyepieces, red dot finder, motor drives, stainless steel tripod, NexStar computer, software to control the scope from your computer, and more.



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21st century Celestron go-to . . . at a 1984 price.

If you fondly remember the original orange-tube Celestron C8 – the scope that made amateur astronomy affordable – the **Celestron NexStar 8i Special Edition** will bring back the good old days . . . at a low price straight out of the 1980s!

The scope has a modern anodized version of Celestron's vintage orange and black paint, a convenient go-to computer with no-guesswork *SkyAlign* technology, and the bright images of Celestron's best StarBright XLT multicoatings.

The most amazing part? This 21st century telescope is available for less than the price of a C8 from 1984 that didn't even have a computer.

Amateur astronomy has changed a lot over the past 20 years. But the value and performance of a Celestron C8 have always been standards you can rely on.



\$1399

Sphinx go-to is as simple as point-and-click.

The **Vixen Sphinx** go-to equatorial mount's StarBook hand control makes astronomy easy. Simply move a cursor to an object on the Star Book's 4096-color LCD star chart screen and the Sphinx moves to that object. That's all it takes to find your way around the sky with a Vixen Sphinx.



Vixen StarBook hand control showing star chart display

As a Vixen stocking dealer, we keep Sphinx mounts in inventory for use with your own optics. We also stock complete Vixen mount and telescope packages that use Vixen optics ranging from a 3.2" refractor up to 8" reflectors and catadioptric scopes.



\$3299
ED81SWT-Sphinx
3.2" f/7.7 ED apo
Vixen refractor on
Sphinx go-to mount

Big binoculars. Bright images. Little prices.

You don't need a telescope to enjoy astronomy. Many deep space sights – nebulas, galaxies, star clusters – are all visible through large aperture binoculars, as are myriad craters, seas, and mountains on the Moon.

The **Meade 9 x 63mm** roof prism, to the right, shows you detailed views of the sky for very little cash compared with other roof prisms its size. It has fully multi-



\$179

coated high transmission BaK-4 prisms. The big **Celestron 25 x 100mm Skymaster**, below, gathers as much light as two 4" rich field telescopes, one for each eye. The similar but smaller **20 x 80mm Skymaster** at \$239, not shown, has the light-gathering of a pair of 3.1" rich field telescopes. Both are serious binos for serious deep space viewing.



\$329

Scopebuggy makes it easy to move your scope.

A **Scopebuggy** telescope transporter has big 10" pneumatic tires, a pivoting front wheel, and a pull handle that make it

so easy to move scopes weighing up to 300 lbs. that even a child can do it.



\$265

An astonishing deal on a go-to refractor.

What makes this 3.1" **Meade ETX-80AT** go-to refractor such a good deal for only \$279.99?

Just look at what you get for that price. An 80mm f/5 refractor optical tube with multicoated achromatic optics, go-to altazimuth mount, AutoStar computer hand control with a database of over



\$279.99
freight paid

1400 celestial objects it can find for you, adjustable height metal tripod, tripod carrying case, two Super Plössl eyepieces, built-in flip-lever Barlow, an instructional DVD, 19,000,000 star and object planetarium software – and more! And if that's not enough, you get free freight, too!

This is no ordinary starter scope. This is a full-featured Meade ETX that can keep you and your family happily scanning the skies for years to come, at a low price you can afford today.

Know your zip code? You can use a Meade Premier ETX.

All you have to do to find your way around the sky with your new 3.5" to 5" **Meade Premier Series ETX** Maksutov-Cassegrain is tell it your zip code.

Patented **Meade Level North Technology** automatically levels the optical tube, finds North, sets the time, and moves to the vicinity of two alignment stars. Simply check to be sure the wide angle red dot finder is centered on those stars. Then tell your ETX which of the 30,000+ objects in its memory you want to see, and the scope takes you there automatically.

It doesn't take a degree in rocket science to use an ETX Premier Series scope. It's almost as simple as simply knowing where you live!

Each Premier ETX comes supplied with a field tripod, red dot finder, 26mm Super Plössl eyepiece, and more.



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freight paid

astronomics. No hard sell. No guesswork. Just honest advice, the time to make sure you get the right telescope and accessories, and a good price. Call us toll free at (800) 422-7876 and find out for yourself.

We actually stock TeleVue.

Others may say they carry **TeleVue** telescopes, but we actually keep **TeleVue** scopes in stock. Dozens of them.

A few of the TeleVue scopes we have in stock for immediate shipment are listed below. These are optical tubes only, with dust covers and carrying case.

TV-60, 2.4" f/6 apo \$795⁰⁰
TV-76, 3" f/6.3 apo 1275⁰⁰
TV-85, 3.35" f/7 apo 1680⁰⁰
TV-102, 4" f/8.6 apo 2200⁰⁰



NP-101 \$3595

Does your dealer?

The following scope packages (for use on your own mount) with a star diagonal, Plössl eyepiece, tubing, dust covers, and case, are also in stock.

TV-76, 3" f/6.3 apo 1675⁰⁰
TV-85, 3.35" f/7 apo 2080⁰⁰
TV-102, 4" f/8.6 apo 2635⁰⁰
Renaissance, 4" f/8.6 brass 2935⁰⁰
NP-101, 4" f/5.4 Petzval apo 3595⁰⁰

And we stock all TeleVue eyepieces and accessories for immediate shipment.

Barlows double your available eyepiece powers.

Today's multicoated Barlows can improve your eyepiece performance and double your eyepiece collection. Here are some of the 1.25" Barlows we stock:

Celestron 2x Omni \$39⁹⁵
2x X-Cel ED 77⁹⁵
2x Ultima 3-element apo 79⁹⁵
Coronado 2x for solar observing 129⁰⁰
Meade #124 2x for ETX70 39⁹⁵
#126 2x for ETX90/105/125 47⁹⁵
#140 2x 3-element apo 49⁹⁵



Meade 2x 4-element 5000 159⁰⁰
3x 4-element 5000 159⁰⁰
5x 4-element 5000 159⁰⁰
Takahashi 2x 169⁹⁵
TeleVue 2x 105⁰⁰
3x 190⁰⁰
2.5x 4-element Powermate 190⁰⁰
5x 4-element Powermate 190⁰⁰
Vernorscope 2.4x Dakin 169⁰⁰
Vixen 2x 49⁰⁰
2x DX 3-element 115⁰⁰
3x 65⁰⁰

Dioptrx lenses eliminate eyeglasses for observing.

TeleVue Dioptrx astigmatism-correcting lenses attach to TeleVue eyepieces so you don't have to wear eyeglasses to observe.

TeleVue Dioptrx lenses are available in 0.25 diopter steps from 0.25 to 2.50 diopters. Each is made of preci-



\$98

sion-ground multicoated optical glass. They work with the following TeleVue eyepieces only: 26 and 31mm Type 5 Naglers; 22, 27, 35, and 41mm Panoptics; 22, 40, and 55mm Plössls; all Type 4 Naglers; and all Radians.

\$299 for a Meade Deep Sky Imager.

The **Meade Deep Sky Imager** takes full color photos of galaxies, nebulas, star clusters, the Moon, and planets at a fraction the cost of a CCD camera.

The DSI is a one-pass color camera, so



there's no need to take multiple exposures through filters and combine them later to come up with a color image.

The easy-to-use Meade Deep Sky Imager also includes a USB cable and the Autostar Software Suite of imaging control software in its low price of only \$299.

The right accessories make your observing easier.

A red flashlight protects your dark-adapted night vision while you observe. **Celestron's** variable brightness red flashlight, our part #VLED, costs \$19.95.

The **Rigel Systems** continuously variable brightness dual red LED flashlight shown to the right, our part #4591, is \$24.95.

Rigel's very handy two-color variable brightness light (#4592) – dual red LEDs for reading star charts, dual blue-white LEDs for setting up or taking down your scope – is only \$29.95.

Vibration suppression pads under the legs of your telescope tripod virtually end the tremors that blur your view for a few seconds every time a breeze comes up or you touch the scope to focus.

A set of three **Celestron** anti-vibration pads, our part #VSP, costs \$49.50.

The **Meade** #895 set of three anti-vibration pads to the right costs \$49.95.

Either set takes the constant vibration and frustration out of observing and are well worth their low cost.



The **Celestron Power Tank** rechargeable 12-volt batteries have the power you need to run your telescope and accessories all night long. You can recharge them hundreds of times, saving you hundreds of dollars over the cost of buying new flashlight batteries every few weeks. Each has two 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; a built-in recharger; shoulder strap; carry handle; and more.

The 7 amp hour capacity Power Tank shown above, our part #4512V, is only \$59.95. The 17 amp hour capacity Power Tank, our #4517V, is only \$89.95.

Antares 7 x 50mm and 12 x 80mm right angle finders cost from \$79.95 to \$184.95. They're available in either size in Celestron black, Meade blue, or gloss white. Choose from standard mirror-image versions or erect right-reading models that show the sky the way it appears on star charts.



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Price match fine print: competitor's price must be verifiable and available nationally; chain store, close-out, and going-out-of-business prices are excluded; no retroactive price matching; a package price must be from a single competitor.

PROFILE

In a rare personal interview, Jack Horkheimer talks about considering the priesthood, cheating death, and bringing the stars into millions of living rooms.

/// BY WILLIAM SCHOMAKER

America's stargazer

Whether you absolutely love it, love to hate it, or can't quite figure it out, Jack Horkheimer's PBS show *Jack Horkheimer: Star Gazer* is an unforgettable, 5-minute serial on naked-eye astronomy. It is — for lack of a more appropriate term — unique.

"Greetings, greetings, fellow stargazers," beams a buoyant Horkheimer from behind his expansive director's desk at the Miami Planetarium in Miami. "I always start the show with that line," he confides, "because I want my viewers to feel like welcome partners in each episode."

Some viewers tune in to get a chuckle out of watching Horkheimer slide around on space beams like a sugar-crazed 6-year-old, delivering his lines with a quirky, yet endearing, bravado reminiscent of Rip Taylor, Charles Nelson Reilly, Captain Kangaroo, and Mr. Wizard rolled into one. Others tune in to get a weekly dose of Horkheimer's night-sky wisdom. Whatever the reason — Horkheimer says he doesn't care — the 6 million viewers who tune in each week to an episode of *Star Gazer* come away knowing a little bit more about the night sky and about their own place in the universe.

"A planetarium show, *Astronomy* magazine, Internet sites on space, and my television show: These are all bricks in the

cosmic yellow brick road that leads to cosmic Oz, which is an understanding of who and where you are in time and space. And that's different for each person," says Horkheimer, who writes, hosts, and produces *Star Gazer*. "I can't completely comprehend the universe, but I can comprehend a portion of it. That's what I find so magnificent, that I'm part of the universe that I'm contemplating."

Jack's star-formation

Born into a wealthy publishing family in Randolph, Wisconsin, June 11, 1938, Horkheimer began with the name Foley Arthur Horkheimer. After graduating Campion Jesuit High School in 1956, he traveled the country, playing jazz piano and organ to packed nightclubs under the pseudonym Horky. Feeling he needed a more macho stage name, Horkheimer's agents at the Artists Corporation of America made an exec-



FROM BOYHOOD (left) Jack Horkheimer demonstrated showmanship. He honed his stage presence as a jazz musician (above).

ALL HISTORICAL PHOTOS COURTESY JACK HORKHEIMER

utive decision and began booking him as Jack Foley, which he later adapted to Jack Foley Horkheimer.

Although Horkheimer was always fascinated with the stars, thanks to the encouragement of his grandfather and the idyllic darkness of mid-century Wisconsin skies, he pursued becoming a priest, doctor, and playwright before being compelled to get in front of the camera and talk about the wonders of astronomy. He attributes the latter calling with a "transfiguring moment" that occurred during a peak of spiritual crisis, borne out of years of fighting a debilitating congenital lung condition.

In 1964, at the age of 26, he moved to Miami in search of respite and recovery from his illness. Horkheimer sought an outlet through which he could channel his interests in amateur astronomy, art, and

William Schomaker is a contributing editor of *Astronomy*.

/// STARGAZING FOR ABSOLUTE BEGINNERS

Horkheimer is producing a DVD to be titled *Stargazing for Absolute Beginners*. It's a project he's longed to work on for 10 years — a goal born out of a frustration over the lack of suitable material for novices to the night sky.

"This DVD is for people who don't know squat," says Horkheimer. "I start with the assumption that whoever watches this doesn't know that the Sun is a star or that all of the stars we see at night are other suns."

Slowly and methodically, Horkheimer plans to help build a foundation for understanding the universe, a challenge that is very close to his heart. "The DVD is so serious to me that it has my stomach churning," he says. "I'm writing this thing in my dreams." — W. S.



NO MORE MEMBERS ONLY jackets for the Star Gazer after 1999. Horkheimer gave up his trademark look of 14 years for a casual blue sweater and khaki trousers. “I grew to hate [the jacket],” Horkheimer says, “because it became so antiquated.” BILL WISSER

writing to turn people on to the stars. The late Arthur Smith, then president of the Miami Museum of Science, encouraged Horkheimer to write shows for the cash-strapped Miami Space Transit Planetarium (now called the Miami Planetarium at the Miami Museum of Science).

“I ran the planetarium as a volunteer and was handed the perfect opportunity to combine my playwriting skills with my science background to produce astro-docudramas with live star shows and music, which nobody had been doing at the time,” says Horkheimer.

In 1967, Horkheimer took a full-time job with the Miami Museum of Science. In 1973, he was named executive director of the Miami Space Transit Planetarium, a title he proudly retains 33 years later. And with award-winning, multimedia planetarium shows like “Child of the Universe,” “Star Bound,” and “Mother Won’t Let Me Ride in a Flying Saucer,” Horkheimer quickly gained international renown with astronomers and planetarium audiences. “I don’t know of anyone lasting longer as director of a planetarium than he has,” says acclaimed amateur astronomer David Levy.

Throughout the early 1970s, Horkheimer served local Miami media as a science interpreter, lending his wisdom to numerous news programs as well as appearing on children’s television shows such as *Bozo the Clown* and *Skipper Chuck’s Playhouse*. Horkheimer also caught the interest of producers at local PBS affiliate WPBT, who approached him to create a series of half-hour documentary-style shows called *Horkheimer’s Heavens*.

Horkheimer said yes, on one condition — that they help him create a series of 5-minute programs on naked-eye stargazing. WPBT agreed, and *Jack Horkheimer: Star Hustler* was born November 6, 1976. The early shows, however, were nothing like

Horkheimer has a special fondness for the diametrically opposed constellations Orion and Scorpius and their headlining stars, Betelgeuse and Antares.

"Kids love Antares," says Horkheimer, "because it's red, and it's where the heart should be in the scorpion, so it's also appropriate. And then [you] tell them about Betelgeuse, which is even bigger. If you've never heard this stuff before, it blows your little blue booties off because it's fun, fun, fun."

He also enjoys the myths that prop up the constellations. "Gaia sent the scorpion to quail the braggadocio of Orion because he boasted that no mortal creature could subdue him," he says. "I just love the way the stories are constructed to explain reality. When Orion rises, Scorpius has just set. When Scorpius rises, Orion has just set, and the reason we don't see Orion in the same sky as Scorpius is because Orion wants to put as much distance between himself and the scorpion as possible." — *W. S.*

what viewers have come to expect from Horkheimer today.

The Star Gazer's evolution

"For the first 9 years, I was serious and very laid back. I'd smile and I was gracious, but I spoke to the camera very calmly and quietly, one on one," says Horkheimer, as he opens a wooden wall panel behind his desk and slides a VHS tape into a hidden deck. In "Helios: Marvelous Monster Over Miami" (one of the original half-hour shows in the *Horkheimer's Heavens* series) a trim, mustachioed Horkheimer sporting a full head of hair stands behind two bikini-clad sunbathers and waxes poetically about the Sun's marvelous power.

With a wide-collared shirt open to mid-chest, he looks more like Tom Selleck with straightened hair than the middle-aged guy in a Members Only jacket — his trademark look until 1999 — that people so closely associate with Horkheimer.

When *Star Hustler* went national in 1985, WPBT executive producer Ed Waglin, whose prior production credits include television greats such as *The Jackie Gleason Show* and *Playhouse 90*, felt Horkheimer's tranquil demeanor didn't jive with the sense of urgency the show was intended

to convey to its viewers. Horkheimer's suave, news-magazine-

style delivery at that time is eerily reminiscent of John Stossel's persona on ABC's *20/20* today. Waglin reminded Horkheimer they weren't playing to people who were already converts to astronomy, but to people who needed nudging to get outside and look at the stars.

"Ed is the one who encouraged me to create the *Star Gazer* character," recalls Horkheimer. "We'd do take after take and I'd say, 'Ed, I feel like I'm being a phony, screaming like this.' He said, 'Jack, your character has to be different if we're going to pull this off.' And I said, 'Well this is certainly different from any Jack Horkheimer that I know.' I hated that character and wanted to dump him for 2 years. I wouldn't even watch my own TV show. Now, I like him. I realize that he is a character, that it's not me."

Today, Horkheimer rarely breaks from the character who has brought him acclaim and generated so much interest in the stars. He says he sustains his enthusiasm for his devoted fans, for whom he wants to be an encouraging example.

"I've got to make people laugh and smile and think, 'That guy has so much energy, where the hell is he going with this?' and get them to love the night sky as much as I do," says Horkheimer.

"I'm really proud of Jack," says Waglin, now retired from WPBT. "Most of what he'd been doing up until the time we went

national was lecturing. I encouraged him to be an entertainer. It was a wonderful new way to deal with [astronomy] that no one else had the courage or ability to pull off."

Share the wealth

Horkheimer surrounds himself with a small staff of loyal, like-minded astronomy enthusiasts. "We haven't had much luck with professional astronomers on this staff," says Horkheimer. "The people who stick around are the enthusiastic amateurs who actually get out and look up at what's going on in the sky." A knowledgeable and eager staff, he says, makes show production run like clockwork. Still, producing a show like *Star Gazer* isn't simple, and it's not cheap.

Fellow astronomy enthusiast — and writer, producer, and host of the daily 90-second radio series *Earth and Sky* — Deborah Byrd knows no matter how long you've been doing it, nothing is ever simple in show business. "Producing a regular show like that definitely has its challenges. It means working holidays, birthdays;

WATCH STAR GAZER

Download free episodes of *Star Gazer* from www.jackstargazer.com or check your local PBS station's programming schedule at www.pbs.org/stationfinder/index.html for days and times.

sickness, health, and all of the rest of it. Not to mention the challenges associated with keeping it fresh," she says.

From the beginning, Horkheimer insisted he do the show as the planetarium's executive director, and he hasn't earned a dime from *Star Gazer*. "This show gives the museum more publicity than anything else we've ever done," says Horkheimer.

All proceeds from the sale of videos and DVDs go into the show's general operating budget. In return, WPBT guarantees *Star Gazer* is distributed freely via satellite to more than 200 PBS stations across North America, in addition to the Armed Forces



JUNE 11, 1938

Born Foley Arthur Horkheimer in Randolph, Wisconsin

1953–1954

Hosted two radio shows for WBEV out of Beaver Dam, Wisconsin

1956

Graduated from Champion Jesuit High School

1956–1960

Toured the country during summers as a professional jazz organist and pianist

1957

Had to leave Honolulu Academy of Fine Arts because he was suspected of having tuberculosis

1963

Graduated from Purdue University as distinguished scholar with Bachelor of Science degree

1964

Studied playwriting and directing as graduate student at Purdue

1964

Wrote award-winning play called *If the Shoe Fits, Eat It*

1964

Moved to Miami to recover from illness. Began volunteer work at the Miami Space Transit Planetarium

Horkheimer has received numerous awards during 33 years in the business. These include the 2000 Klumpke-Roberts Award (for popularizing astronomy) from the Astronomical Society of the Pacific, the Outstanding Achievement Award from the Astronomical League, and a 25th Anniversary Classic Telly Award for *Star Gazer*. In 2001, Asteroid 1999 FD₉ was named Asteroid Horkheimer by the International Astronomical Union in recognition of his life-long achievements.

Horkheimer says that although he appreciates all of the awards, he is most fond of the asteroid and a poster signed by Pluto's discoverer, Clyde Tombaugh. The inscription reads, "To Jack, the Star Hustler. Thank heavens I kept looking up!" Horkheimer says: "He was crazy about the show and his wife hated it. He would go to bed early and have her wake him up so he could catch the show. I always thought that was so funny." — W. S.



BILL WISSER

"I'VE GOT TO MAKE PEOPLE LAUGH AND SMILE." Due to a congenital lung ailment called bronchiectasis, Horkheimer has been close to death on several occasions. He's already erected a tombstone for himself next to his mother's and father's at a tiny cemetery in Randolph, Wisconsin. True to Horkheimer's irreverent sense of humor, the epitaph reads, "'Keep looking up' was my life's admonition. I can do little else in my present position."

Network, NASA's Central Operations of Resources for Educators, and the United States Information Agency's WORLDNET. The show also relies on underwriting from corporations such as Meade Instruments and Noven Pharmaceuticals.

No telescope required

Although Horkheimer has an insatiable love for the night sky, he doesn't consider himself an astronomer, preferring the tag of science dramatist or astronomy popularizer instead. And while he gets plenty of criticism from professional astronomers for

being too campy and simplistic, Horkheimer and his staff are unfazed.

"We get letters from people all the time, saying, 'You didn't say anything about the new supernova or new galaxy that was discovered last week,'" says Bill Dishong, Horkheimer's associate producer, assistant director, and devoted planetarium technician of 30 years.

"So what? Nobody can see that stuff anyway. We're trying to get people to go outside and look up at the things you can see without a telescope."

"We need to have someone who is just plain passionate turning people on to the night sky," adds Levy. "And Jack fits that role perfectly."

Unfortunately, last year was exceptionally hard on Horkheimer,

with a surprising colon-cancer diagnosis and subsequent treatment. Yet somehow he still manages to maintain the perfect embodiment of his trademark signoff — "Keep looking up!" — he uses to close each *Star Gazer* episode.

"You just have to find a way to keep going. 'Keep looking up' is to say, be optimistic, be encouraged, keep a stiff upper lip, and keep up the good work. It was a directive that had, and still has, a strong double entendre," says Horkheimer.

"Stargazing is all about where you are in time and space. The reason people get out their telescopes and attend star parties is because they are trying to peer out over the horizon to find their place in the universe. And if I can help them find that, that's all that matters." ■

ONLINE
EXTRA

Read more about America's star-gazer at www.astronomy.com/toc.



1967

Joined full-time staff of Miami Museum of Science

1973

Named director of Miami Space Transit Planetarium

1973

Gained an audience as a local science commentator for Miami

1976

Five-minute program, Jack Horkheimer: Star Hustler, debuted on Miami's WPBT Channel 2

1985

Star Hustler went national

1997

Star Hustler became Star Gazer

2001

Asteroid 1999 FD₉ named 11409 Horkheimer by the IAU

2003

Star Gazer and WPBT Channel 2 win Classic Telly Award.

2005

Began night-sky DVD project for novices

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IMAGINOVA

EQUIPMENT REVIEW

Say “goodbye” to eye fatigue by adding Denkmeier’s Binoviewer to your observing kit. /// BY MIKE MARCOTTE

Eyes wide open

Most observers find binoculars easier to use than a telescope. Enter the binoviewer, an accessory with an internal prism that sends light to two eyepieces, letting your telescope mimic binoculars. When I unpacked the Denkmeier II Powerswitch Binoviewer, I thought, “If this

thing matches the way it looks and feels, Denkmeier Optical has a real winner.” When I looked through the binoviewer, my thought changed to “Oh, wow!”

I pointed my Schmidt-Cassegrain telescope (SCT) at the First Quarter Moon. I quickly called my wife and a couple of neighbors over to enjoy the view. All concurred with my “wow” assessment. I then spent the next few hours enjoying the most spectacular views of the Moon, Jupiter, and Saturn I have ever seen through this scope. And all without the “face-muscle fatigue” that plagues every astronomer who has spent serious time at an eyepiece.

Mike Marcotte is a retired firefighter who observes in and around El Paso, Texas.

Binoviewers are not new to the world of amateur astronomy. Denkmeier Optical, however, has taken telescopic binoviewing to a new level with the features incorporated in (or attached to) its Denkmeier II Binoviewer series. The specific binoviewer I reviewed was the Denkmeier II Powerswitch for SCTs.

My admiration started with the binoviewer’s eyepiece holders, each of which has a self-centering feature and a diopter adjustment. The self-centering feature keeps the two eyepieces parallel, which establishes a single image. It does this with a firm feel, yet the adjustment easily moves to accommodate the next observer. The diopter adjustment works equally well, and it was a snap to micro-focus each eyepiece independently without touching the telescope’s focus knob.

The next feature — and it’s a great one — is a patent-pending innovation called the “Power x Switch.” This device provides low, mid-range, and high magnifications with a single set of eyepieces. The Power x Switch accomplishes this with slides that extend on either side of the Binoviewer. If you are using an SCT, then nothing else needs to be attached. If you are using a refractor or

/// PRODUCT SPECIFICATIONS

DENKMEIER II POWERSWITCH BINOVIEWER FOR SCTs

Clear aperture: 26mm

Coatings: Dielectric multi-coatings

Eyepiece holders: Interpupillary distance variable from 2" to 3" (50mm to 75mm)

Dust protection: Machined, threaded caps

Case: Aluminum with locks

Price: \$1,295; note: Binoviewers start at \$349; Power x Switch Diagonals are priced from \$389 to \$599.

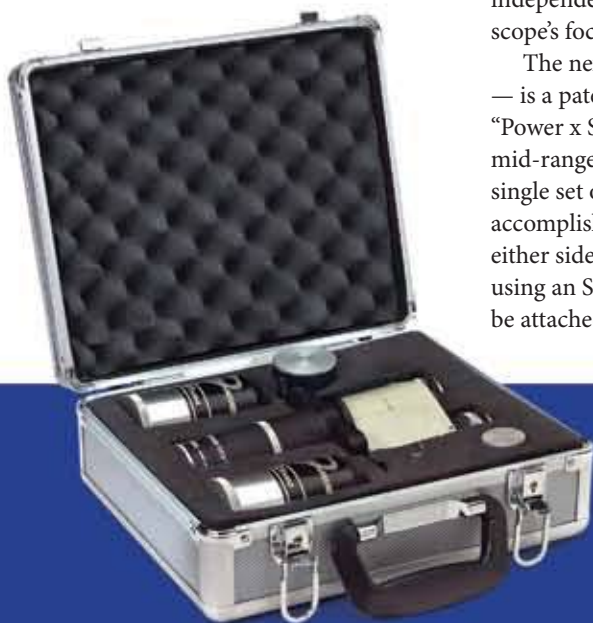
Contact information:

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Newtonian reflector, you must add a second optical component called the Multi-Purpose OCS Cell, which is included. The Power x Switch creates different magnifications depending on the telescope used. The included instructions provide details for each telescope design.

I also used Denkmeier’s new Power x Switch Star Diagonal #S2 with the Denkmeier II Binoviewer. This device incorporates both a focal reducer and a Barlow lens into a top-quality 2" star diagonal. Denkmeier claims this setup will be standard equipment with all SCTs in the near future, and I agree with the idea.

With Denkmeier’s 21mm wide-field eyepieces (optional) installed in the binoviewer, a simple slide brought the focal reducer into the optical path. This effectively transformed the 21mm eyepieces into 42mm ones. With the other slide, I was able to “double up” the eyepiece magnifications, emulating 10.5mm focal lengths. This brought a new dimension to my lunar



ANY DENKMEIER model you choose comes packed in a sturdy, lockable aluminum carrying case with space for accessories.

THE DENKMEIER II BINOVIEWER lets you keep both eyes open when using your telescope and minimizes eye fatigue. With the Power x option (shown), you can select from three different focal ratios, effectively tripling your eyepieces.

ALL PHOTOS: ASTRONOMY: WILLIAM ZUBACK



DENKMEIER'S POWER X SWITCH DIAGONAL can be added later if you choose a binoviewer without one.

EYEPIECES fit into self-centering holders, and each focuses individually. Denkmeier sells 14mm and 21mm eyepieces specially made for its binoviewers.

observing, and I was knocked out by awesome views of globular and open star clusters. Jupiter and Saturn (even low on the horizon) were virtual showstoppers. Both the eyepieces and the star diagonal provided outstanding contrast and sharpness to the edge of the field of view.

Denkmeier manufactures several models of diagonals and binoviewers. The different configurations assure one binoviewer will work with your telescope. To find out which one is best for your application, visit Denkmeier's web site at deepskybinoviewer.com. It's packed with useful information to

help you make your choice. The web site also has information on focal reduction, eyepiece selection, and binoviewing in general, plus downloadable product manuals.

One factor you have to consider about this system is its weight (20 ounces). You'll need to protect your drive motors by properly balancing your scope, especially fork-mounted Schmidt-Cassegrain telescopes. Your telescope's manufacturer or an astronomy equipment dealer will provide you with options for adding counterweights.

Unlike other binoviewer manufacturers, Denkmeier provides many options to suit

pocketbooks of almost every size. You can spend as little as \$349 for a Most Basic Standard Binoviewer, or as much as \$2,000 for a complete system that adds a Power x Switch Diagonal and eyepieces.

But there's no argument that the quality and craftsmanship are superb in all aspects, even down to the machined lens caps. After using the Denkmeier II Binoviewer system for a few weeks, I judge it well worth the investment. In fact, with all the magnifications possible if you purchase both sets of eyepieces — the 21mm and 14mm — you'll seldom use anything else. ■

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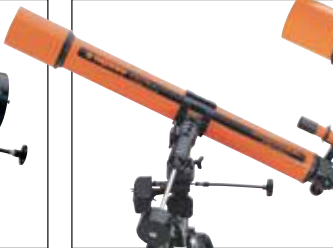


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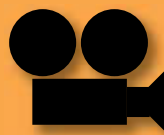
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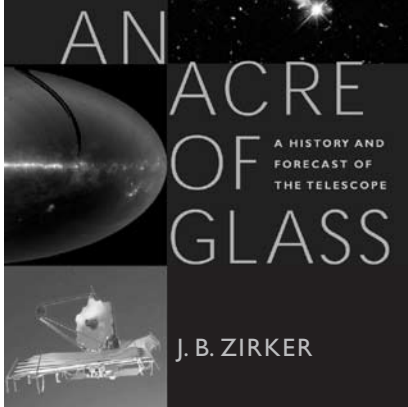


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 Michael Barbee, Corporate Circulation Director. Date: September 29, 2005.

{ BOOK REVIEWS }

Updating a classic

Atlas of the Moon

Antonín Růkl, 224 pages, Sky Publishing Corp., 2004; hardcover, \$44.95

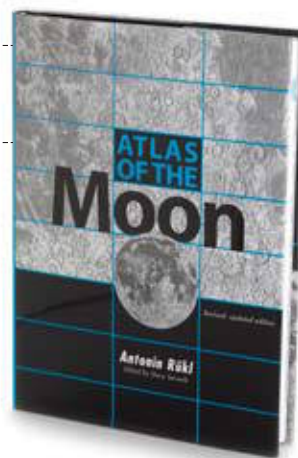
Having heard there is an updated edition of *Atlas of the Moon* by Antonín Růkl being released, I was curious to see how an already great resource could be improved. I found the information is updated, the picture quality is better, and the charts are easier to use at night.

The atlas consists of 76 sections about the nearside of the Moon, making it especially useful for lunar observers. Růkl has incorporated the latest images taken by the Clementine, Galileo, and Lunar Prospector spacecraft. Results from a special search for ice on the Moon's south pole by the Arecibo Observatory also are included. Data from these missions have provided scientists with corrected information about the south polar region.

Obsolete terms such as "Walled Plains" and "Ring Mountains" have been removed. For example, on plate 72, Clavius was described as a "Walled Plain" in the old edition. In the revised version, Růkl writes it is a "very large crater, or crater-to-basin transition, with huge mountain rings." This description reflects terminology geologists use today.

The most significant improvement with the atlas is that the background color and the grid lines for each of the 76 maps have been changed from the original red. The colors of the latitude and longitude lines and the numbers of the adjacent section have also been changed. This color change creates a dramatic improvement, making the maps easier to read during night observing sessions.

Růkl defines apogee and perigee and explains the changes in angular diameter. He also discusses the properties of synchronous rotation; this is when the Moon completes one rotation on its axis in the same time as it takes to orbit Earth.



THIS must-read for all lunar observers has been further improved.

There is also an excellent explanation on why we can see up to 59 percent of the lunar surface due to the Moon's oscillating motion, called libration. New libration charts have been incorporated into the book too. Růkl addresses lunar phases and the difference between the sidereal month, 27.3 days, and synodic month, or lunation, of 29.5 days.

This atlas gives the beginning amateur astronomer clear and understandable explanations of lunar dynamics from one lunation to the next. For the advanced observer, being able to calculate the co-longitude, or sunrise/sunset line, through the year 2030, is a long-term benefit.

The maps give detailed renditions of lunar features with a scale — a disk size of 1,448mm (about 57 inches) — that makes it an excellent resource for any observer.

— **DAVID O. DARLING** is the assistant recorder for the lunar transient phenomena section of the Association of Lunar & Planetary Observers.

Satellites: Orbits and Missions

Michael Capderou, 544 pages, Springer Verlag, 2005; paperback, \$89.95

This book begins with details on the mechanics of satellites' orbits. Then it dives into different types of orbits: circular, elliptical, geosynchronous, and Sun-synchronous. There's also a great explanation of the Lagrange points. This book mentions 1,200 satellites in a range of fields — astronomy, meteorology, telecommunications, and positioning. Capderou includes short summaries of the orbits for some of the satellites, and several also have a diagram of their track. In addition, a CD-ROM allows you to follow hundreds of satellite tracks. This book is for those with a serious interest in orbits, and a firm background in calculus.

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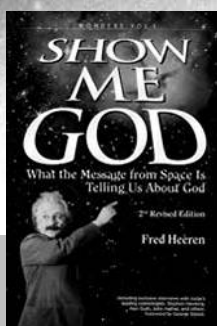
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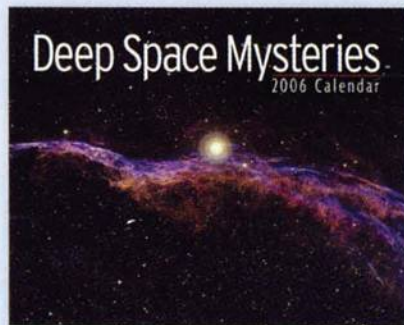


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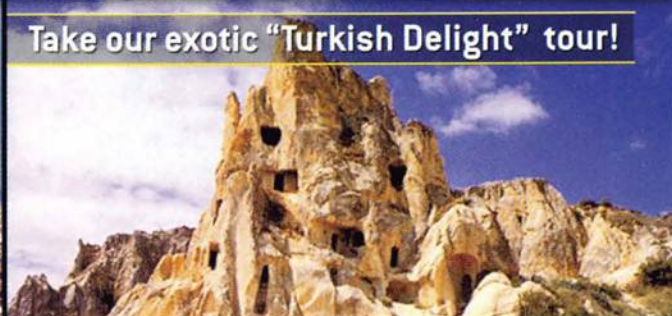
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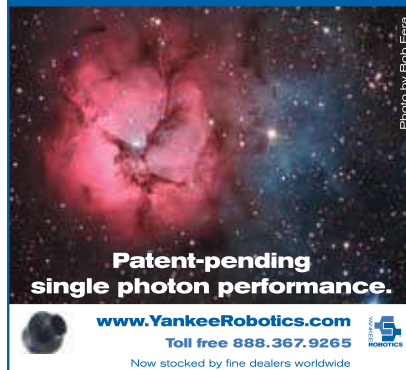


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{ COMING EVENTS }

JANUARY 2006

MARCH-APRIL 2006

Some observers' spouses do not share their partner's enthusiasm for the night sky. If this is the case for you, a star party is not an ideal couple's getaway. While the camaraderie and workshops of an astronomical gathering thrill you, your better half may be bored senseless



MIKE REYNOLDS

A TOTAL SOLAR ECLIPSE, seen in this April 2005 image, will call skygazers worldwide this March to the Mediterranean Sea. Two groups touring with *Astronomy* magazine will watch the celestial show from open water and the Turkish city of Cappadocia.

before your Messier-marathon chase reaches the Wild Duck Cluster.

Don't despair — there is a vacation solution that permits you to pursue your astronomy interest without overwhelming your disinterested family with white-light policing or instrument chatter.

Many tour agencies offer astronomy-oriented trips to exotic locations. Often, major celestial events are visible only from hard-to-reach regions, like open water or remote deserts. These companies make sure adventurous observers see these events while their families are entertained.

Astronomy magazine has joined with Astronomical Tours for two expeditions

to chase the March 29 total solar eclipse. Join Editor David J. Eicher and Associate Editor Michael E. Bakich on a land and cruise tour of Italy, Greece, and Turkey. The trip begins March 18 in Venice and includes stops in Rome, Florence, Naples, Athens, Mykonos, and Kusadasi. The schedule provides ample time to shop, take in the local culture, marvel at the ruins of ancient Greece, and appreciate the art of Renaissance Italy.

A ship will take the group into the Mediterranean Sea for an unhindered view of the Moon eclipsing the Sun.

Senior Editor Richard Talcott will lead the second trip through Turkey beginning

March 26 in Istanbul. This tour will explore modern Turkey, as well as journey through history to ancient civilizations. Sightseeing will include visits to Tokapi Palace and the ruins of Ephesus.

The group will view the solar eclipse from the picturesque city of Cappadocia.

Be sure to make a reservation soon with Astronomical Tours — available spots fill up quickly.

For more information about these and other excursions planned by Astronomical Tours, call Jen Winter at 660.747.9458; web site, astronomicaltours.net.

JANUARY 6

Far Out Friday

Adler Planetarium and Astronomy Museum, Chicago. On the first Friday of every month, the Adler hosts an evening of astronomy-related fun, including observing, lectures, planetarium shows, and tours of the facilities. For more information, call 312.922.7827; web site, www.adlerplanetarium.org.

JANUARY 21–28

Cedar Key Star Party

Chiefland Astronomy Village, Cedar Key, Florida. This week-long event offers some of the darkest skies in Florida. Attendees will host three public observing nights for local residents. For more information, visit www.supstateastro.org/stars/cedarkey.html.

JANUARY 21

Regional Meeting of Amateur Astronomers

Gardner-Webb University, Boiling Springs, North Carolina. Sponsored by the Cleveland County Astronomical Society, this event is known unofficially as “Bobfest.” The day will feature observing, lectures, a swap table, and door prizes. For more information, visit www.ccastro.org.

JANUARY 28

Connacht Star Party

Westwood House Hotel, Galway, Ireland. Sponsored by the Galway Astronomy Club (GAC), this 1-day event will be

packed with observing, exhibits, lectures, and workshops. For more information, e-mail the GAC at galwayastro@email.com; web site, www.galwayastronomyclub.ie.

FEBRUARY 20–26

Winter Star Party

Camp Wesumkee, West Summerland Key, Florida. Sponsored by the Southern Cross Astronomical Society. The 12-hour observing sessions at this dark-sky site will provide ample time to target celestial beauties. For more information, call 386.362.5995; web site, www.scas.org.

FEBRUARY 22–26

Deep South Texas Stargaze

Escondido Ranch, McMullen County, Texas. Hosted by the Kingsville Astronomical Society, this gathering is held under nearly 7th-magnitude dark skies. Climate-controlled bunkrooms with showers are available as well as camping and RV sites. In addition to observing, there will be speakers and door prizes. For more information, e-mail Jason Fry at dstsreg@hotmail.com, web site, www.geocities.com/kingsville_astronomical_society/dsts.htm.

FEBRUARY 22–26

Orange Blossom Special Star Party

Alafia River State Park, Lithia, Florida. Although it is easily accessible from Tampa, this site offers tremendously dark skies. In addition to observing, there will be other family-oriented activities, including a hayride, music jam session, and group hikes along the park's trails. No walk-ins will be permitted. For more information, call 813.792.0721; e-mail, dnefarr@msn.com; web site, home1.gte.net/hoffmanc. ■

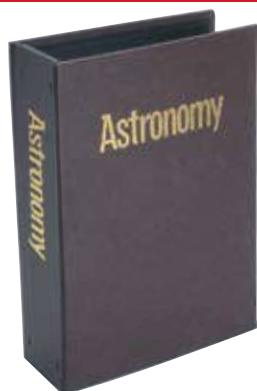
CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

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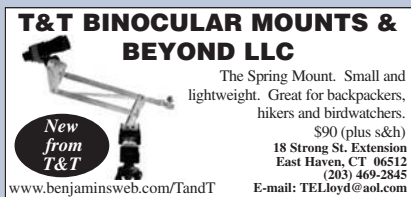
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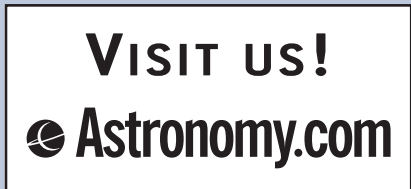

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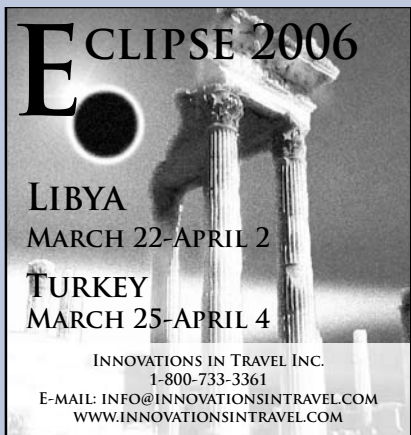
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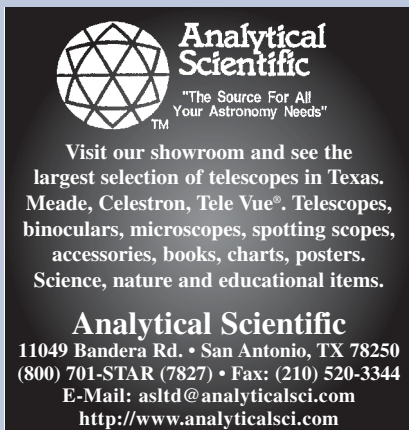
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Reader gallery



DEEP-SKY COLORS

Reflections on the Iris

The Iris Nebula (NGC 7023) lies in the northern constellation of Cepheus the King. This object is a combination of a star cluster and nebulosity, but most of the glory goes to the nebula. Because of the physical processes taking place inside the Iris, astronomers classify it as a reflection nebula. Dust grains within the cloud reflect light from nearby stars. The cloud scatters shorter wavelengths of light — those toward the blue end of the spectrum — more than longer wavelengths. The blue color of our daytime sky is a familiar example of this process. The Iris Nebula measures approximately 6 light-years across and lies 1,300 light-years from Earth.

THE IRIS NEBULA (NGC 7023) (12.5-inch RC Optical Systems Ritchey-Chrétien reflector at f/9, SBIG STL-11000XM CCD camera, Astro-don Series 1 LRGB filters, LRGB image with exposures of 135, 40, 40, and 40 minutes, respectively) /// **DON GOLDMAN, ORANGE-VALE, CALIFORNIA**



THE FULL MOON rises behind the Temple of Poseidon in southern Greece. To complete this image, it took 15 months of repeated attempts to strike the correct balance between the Moon's bright face and the fainter lights illuminating the temple. More amazing is

the fact that this is a single image, not a composite. (Canon EOS 300D digital SLR, Canon EOS 100–300mm zoom lens set for 300mm at f/5.6, 0.6-second exposure at ISO 100, taken May 23, 2005)

/// **ANTHONY AYIOMAMITIS, NEA PALATIA-ORPOU, GREECE**



THE PERSEID METEOR SHOWER is a summer highlight, although the 2005 display wasn't the best. Stacking exposures shows the radiant (the origin point of the meteors) well. (Canon EOS 20D digital SLR, 20mm lens at f/4, ISO 1600, Astro-Physics 1200GTO equatorial mount, 1-minute exposures taken August 12, 2005, from 2:30 A.M. CDT until daylight)

/// **RONNIE AND JOEY WARNER, ROSSVILLE, TENNESSEE**



THE RING NEBULA (M57) in Lyra is the most famous planetary nebula even though it's neither the biggest nor the brightest. (3-inch Stellarvue SV78-S refractor piggybacked on a Meade LX200, Starlight Xpress HX916 CCD camera, composite of twenty 300-second exposures) /// **ADAM STUART, MIAMI**



VENUS, MERCURY, AND SATURN gathered in June. Venus shone 19 times as bright as Mercury and 33 times brighter than Saturn. (Olympus E-1 digital SLR, 40–150mm Zuiko lens at 150mm and f/4.5, ISO 200, 2-second exposure taken June 27, 2005, at 19h25m UT) /// **MILJENKO KIS, PRELOG, CROATIA**



THE NORTHERN LIGHTS mingle with the Big Dipper. The remnants of a jet contrail glow softly below the green curtain. (Nikon D-100 digital SLR, 16mm Nikkor lens at f/4, tripod-mounted, 30-second exposure, ISO 800 setting; taken May 15, 2005, at 3:32 A.M. CDT) /// **VIC AND JEN WINTER, WARRENSBURG, MISSOURI**



GLOBULAR CLUSTER M53 in Coma Berenices spans 12.6' and shines at magnitude 7.5. Visually, this object appears best through an 8-inch or larger telescope. (4-inch Takahashi FSQ106N apochromatic

refractor, SBIG ST-2000XM CCD camera, LRGB image with ten 60-second exposures in each channel) /// **CLARENCE AND THORPE SANDERS, ELIZABETH CITY, NORTH CAROLINA**



NGC 6992/5 is part of the Veil Nebula in Cygnus the Swan. This image combines data from two seldom-combined filters: Hydrogen-alpha (H α) and Oxygen III (OIII). The whitish areas in the image glow by the light of excited oxygen atoms, and the reddish glow is light

emitted by hydrogen clouds. (12.5-inch RC Optical Systems Ritchey-Chrétien reflector at f/9, SBIG STL-11000 CCD camera, Astrodon H α and OIII filters, 1.5-hour exposure through each filter) /// **DON GOLDMAN, ORANGEVALE, CALIFORNIA**

Send your photos to: *ASTRONOMY* Reader gallery, P. O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com. Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.



THE SUN seems most spectacular when viewed or photographed through a Hydrogen-alpha (H α) filter. (4-inch Orion ED apochromatic refractor at f/9, Atik ATK-2HS CCD camera, SolarSpectrum 0.65A H α filter, $1/500$ -second exposure [disk] and $1/100$ -second exposure [limb], taken July 6, 2005, at 7h15m UT) /// **ANDREAS MURNER, BREITBRUNN, GERMANY**



GLOBULAR CLUSTER M14 lies in Ophiuchus the Serpent-bearer. Although bright (magnitude 7.6), it's sometimes overlooked for several larger and brighter globulars that populate this area of the sky. (8-inch Celestron Schmidt-Cassegrain telescope at f/10, Starlight Xpress MX-916 CCD camera, LRGB image with exposures of 50, 20, 20, and 30 minutes, respectively) /// **AL KELLY, DANCIGER, TEXAS**



**ONLINE
EXTRA**

To identify the dark nebulae in this image, go to www.astronomy.com/toc.



THE SNAKE NEBULA (B72) stands at the center of a maelstrom of dark nebulae in Ophiuchus the Serpent-bearer. (2.4-inch Takahashi FS60-C apochromatic refractor plus a reducer corrector at f/4.4, SBIG STL-6303 CCD camera, LRGB image with 5-minute exposures in each channel) /// **PAOLO CANDY, CIMINI ASTRONOMICAL OBSERVATORY, ITALY**

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